MATERNAL PARASYMPATHETIC REGULATION DURING DYADIC STRESS: ASSOCIATIONS WITH EMOTIONAL AVAILABILITY, MATERNAL DEPRESSIVE AND ANXIETY SYMPTOMS, AND INFANT DISTRESS

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Maternal Parasympathetic Regulation During Dyadic Stress: Associations with Emotional Availability, Maternal Depressive and Anxiety Symptoms, and Infant Distress

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Abstract

Background: Parents, often mothers, are the primary regulators of infant emotion and physiology. Maternal self-regulation is central to the regulation of another, particularly during stress. Appropriate flexibility in the parasympathetic nervous system (indexed via respiratory sinus arrhythmia, RSA) is associated with positive self-regulation. This dissertation aimed to better understand the factors that influence a mother's parasympathetic regulation during dyadic stress.

Method: A community sample of 83 mother-infant dyads participated in two visits as part of a larger longitudinal study. During the first visit, at infant age 6 months, dyads were filmed as they interacted for 30-minutes at home. This interaction was later coded for maternal caregiving behaviour using the Emotional Availability Scales. Data on maternal self-reported symptoms of depression and anxiety were also collected. During the second visit, at 6.5 months, dyads participated in an experimental stressor, the still face procedure, involving three episodes: baseline interaction; a still face episode wherein a mother is instructed to remain unresponsive to the infant; and a reunion episode, wherein the mother and infant re-establish interaction. Infant distress (coded in 1 second intervals) and maternal RSA data were collected. Multilevel models assessed maternal RSA trajectories and their relation to maternal factors and infant distress in the still face and reunion episodes.

Results: In the still face episode, maternal depressive symptoms, anxiety symptoms and infant distress interacted to predict maternal RSA. Mothers with fewer symptoms of depression and anxiety showed appropriate RSA withdrawal in the context of infant distress, consistent with an adaptive physiological response. In comparison, mothers with more depressive symptoms and high or low anxiety symptoms had increasing RSA trajectories in this context, suggesting less adequate physiological mobilization. Mothers with fewer depressive symptoms and high anxiety symptoms displayed the steepest RSA withdrawal in this episode, suggesting parasympathetic hyperarousal. In the reunion episode, maternal depressive symptoms and emotional availability interacted to predict maternal RSA trajectories. Mothers with fewer depressive symptoms and greater emotional availability displayed trajectories that were consistent with physiological mobilization at the start of the reunion and recovery towards the end. In comparison, mothers with greater depressive symptoms and less emotional availability displayed limited physiological mobilization at the start of the reunion and less physiological recovery towards the end.

Conclusions: Findings illustrate the importance of assessing: (i) physiological regulation dynamically, (ii) maternal mood, anxiety, and caregiving in interaction, and (iii) self-regulation in the context of co-regulation. Further, these results highlight differential parental task demands between the still face episode and the reunion episode. Public health implications and future research are discussed.

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I have lived by the mantra that graduate school is a marathon, not a sprint. It is an arduous process of painful lows and joyous highs. As I complete my dissertation, I find that the marathon metaphor is lacking. Running is often a solo sport. Yet, a dissertation could not be further from a lone endeavour. This finished product is the result of the support and contributions of many.

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Table of Contents

Abstract………………………………………………………………………………….....iii
Acknowledgements………………………………………………………………………...v
List of Tables…………………………………………………………………………….ix
List of Figures……………………………………………………………………………...x
List of Appendices……………………………………………………………………….xi
CHAPTER 1: Introduction……………………………………………………………….....1
Early Caregiving Environments and Regulatory Development………………………....4
The Parasympathetic Nervous System and Polyvagal Theory…………………………8
Parasympathetic Regulation and Psychopathology……………………………………..10
Maternal Parasympathetic Regulation During Dyadic Stress…………………………...14
Examining Dyadic Stress in Early Infancy: Use of the Still Face Procedure…...14
Maternal Parasympathetic Regulation during the Still Face Procedure………....17
Maternal Parasympathetic Regulation in Other Dyadic Stress Tasks…………...26
The Current Study…………………………………………………………………….32
Still Face Episode Hypotheses…………………………………………………..32
Reunion Episode Hypotheses…………………………………………………….34
CHAPTER 2: Method………………………………………………………………………...38
Power Analysis…………………………………………………………………………..38
Participants………………………………………………………………………………39
Participant Demographics………………………………………………………...42
Experimental Stressor – The Still Face Procedure (SFP)………………………………..44
Measures…………………………………………………………………………………44
Demographic Information…………………………………………………………..44
Maternal Depression………………………………………………………………..44
Maternal Anxiety…………………………………………………………………...46
Maternal Emotional Availability…………………………………………………...47
Infant Distress Coding……………………………………………………………...49
Respiratory Sinus Arrhythmia Acquisition and Data Preparation……………….50
Potential Covariates……………………………………………………………………...51
Demographic Characteristics……………………………………………………….51
Maternal Antidepressant Use……………………………………………………….52
Maternal Still Face Manipulation Check…………………………………………...53
Procedure…………………………………………………………………………………...54
Data Preparation and Analytic Approach………………………………………………..57
CHAPTER 3: Results………………………………………..…………………………..…61
Descriptive Analyses, Average RSA Pattern and Covariate Identification……………...61
Factor Analysis of Maternal Emotional Availability Scales…………………………….66
Still Face Episode Results……………………………………………………………….67

Visual Inspection of Average Maternal RSA and Infant Distress Trajectories in the Still Face……………………………………………………………….…..67
Unconditional Models and Covariate Assessment…………………………….…69
Hypothesis 1: Maternal RSA Trajectories as Predicted by Infant Distress and Maternal Depressive Symptoms...74
Maternal RSA Trajectories as Predicted by Infant Distress and Maternal Anxiety Symptoms…………………………………………………………………...78
Hypothesis #2: Maternal RSA Trajectories as Predicted by Infant Distress, Maternal Depressive Symptoms and Maternal Anxiety Symptoms……………..80
Hypothesis #3: Maternal RSA Trajectories and Associations with Maternal Emotional Availability and Infant Distress……………………………………...84
Hypothesis #4: Maternal RSA Trajectories and Associations with Maternal Emotional Availability, Maternal Depressive and Anxiety Symptoms, and Infant Distress……………………………………………………………………...85
Reunion Episode Results…………………………………………………………...86
Visual Inspection of Average Maternal RSA and Infant Distress Trajectories in the Reunion……………………………………………………………………86
Unconditional Models and Covariate Assessment……………………………....88
Maternal RSA Trajectories and their Relation to Infant Distress in the Reunion..93
Hypothesis #5: Maternal RSA Trajectories in the Reunion and their Relation to Maternal Depressive Symptoms…………………………………………………96
Maternal RSA Trajectories in the Reunion and their Relation to Maternal Anxiety Symptoms……………………………………………………………………..96
Hypothesis #6: Maternal RSA Trajectories in the Reunion and their Relation to Maternal Depressive and Anxiety Symptoms…………………………………...97
Hypothesis #7: Maternal RSA Trajectories and Maternal Emotional Availability…………………………………………………………………... 97
Hypothesis #8: Maternal Emotional Availability in Interaction with Maternal Depressive Symptoms and Maternal Anxiety Symptoms to Predict Maternal RSA Trajectories…………………………………………………………………...98
CHAPTER 4: Discussion……………………………………………………………....104
Still Face Episode Findings…………………………………………………………107
Reunion Episode Findings…………………………………………………………...114
Influence of Covariates………………………………………………………………121
Study Strengths………………………………………………………………………124
Limitations and Future Directions…………………………………………………...126
Applied Implications…………………………………………………………………135
Conclusion…………………………………………………………………………...138
Appendices…………………………………………………………………………………...140
References…………………………………………… ……………………………………...147

List of Tables

Table 1. Summary of Studies Assessing Maternal RSA in the Still Face Procedure…………..23

Table 2. Study Hypotheses in a Simplified Format ……………………………………...……37

Table 3. Comparisons Between Dyads in the Final Sample and those Excluded from the Final Sample on Demographic Characteristics …………………….………………………...……41

Table 4. Comparisons Between Dyads in the Final Sample and those Excluded from the Final Sample on Between Subject Variables of Interest …………...………………………………..41

Table 5. Demographic characteristics of the final sample (N = 83)………………...…………43

Table 6. Descriptive Statistics and Correlations for Main Study Variables………..…………. 62

Table 7. Correlations between Maternal RSA, Demographic Factors and Other Potential Covariates…………………………………………………………………………......…65

Table 8. Correlations between the Adult Emotional Availability Scales Total Scores…......…66

Table 9. Final Estimation of the Fixed and Random Effects of the Parsimonious Model Examining Maternal Depressive Symptoms, Maternal Anxiety Symptoms and their Interaction on the Relationship Between Infant Distress and Maternal RSA in the Still Face Episode........82

Table 10. Final Estimation of the Fixed and Random Effects of the Parsimonious Model Examining Maternal Depressive Symptoms, Maternal Caregiving Behaviour, and Their Interaction on the Linear Growth of Maternal RSA in the Reunion Episode…………………..101

List of Figures

Figure 1. Mean Maternal RSA Levels Across Episodes in the Still Face Procedure……......….63

Figure 2. Average Trajectories of (A) Maternal RSA and (B) Infant Distress Across Time in the Still Face Episode……………………………………………………………………...…...68

Figure 3. Fixed Effect Linear Growth Trajectory of Maternal RSA in the Still Face Episode….70

Figure 4. Graphical Depiction of the Fixed Effect of Maternal Average Baseline RSA on Maternal RSA Trajectories in the Still Face Episode…………………………..…...…...….. 73

Figure 5. Graphical Depiction of the Interaction between Maternal Depressive Symptoms and Infant Distress on Maternal RSA Trajectories in the Still Face Episode……………..………….77

Figure 6. Graphical Depiction of the Interaction between Maternal Anxiety Symptoms and Infant Distress on Maternal RSA Trajectories in the Still Face Episode……………..…………….....79

Figure 7. Graphical Depiction of the Interaction between Maternal Depressive Symptoms, Maternal Anxiety Symptoms, and Infant Distress on Maternal RSA Trajectories in the Still Face Episode…………………………………………………………………..…………...….83

Figure 8. Average Trajectories of (A) Maternal RSA and (B) Infant Distress Across Time in the Reunion Episode………………………………………………………………………………87

Figure 9. Fixed Effect Linear Growth Trajectory of Maternal RSA in the Reunion Episode…...89

Figure 10. Graphical Depiction of the Fixed Effect of Maternal Average Baseline RSA on Maternal RSA Trajectories in the Reunion Episode…………………………………..…..…..92

Figure 11. Graphical Depiction of the Interaction of Maternal Caregiving Behaviour and Maternal Depressive Symptoms on Maternal RSA Trajectories in the Reunion Episode……..102

List of Appendices

Appendix A. Demographic and Background Information Form…………………………..…..140

Appendix B. Infant Affect Coding Scheme ……………………………………………..….145

Appendix C. Position of Maternal ECG Electrode Placement …………………………...……146

Maternal Parasympathetic Regulation During Dyadic Stress: Associations with Emotional Availability, Maternal Depressive and Anxiety Symptoms, and Infant Distress

CHAPTER 1: Introduction

Regulation (encompassing the terms emotion regulation and self-regulation) involves coordinated processes across multiple systems to achieve a goal within a specific context (Gross, 2007; Thompson, 1994). Dynamic and integrated responses across neurological, physiological (e.g., autonomic, endocrine, immune), behavioural and affective systems are required (Bridgett et al., 2015; Gross, 2007; Porges, 1994; Thompson, 1994). Humans are born with limited self-regulation abilities and rely on external sources, primarily their central caregivers, to help them maintain stability (i.e., homeostasis) in the face of change (the process of allostasis; McEwen & Seeman, 1999). As such, parents, often mothers, play an essential role in regulatory development, particularly during infancy when they are the central regulator of their infants' emotional and physiological experience (Calkins & Hill, 2007; Feldman, 2006; Sroufe, 1996; Stansbury & Gunnar, 1994; Thompson, 1994).

The early programming of regulatory processes has lifelong implications (Gunnar & Quevedo, 2007), as poorer regulation underlies almost all developmental and mental health difficulties and disorders (Aldao et al., 2010; Compas et al., 2017). Further, the physiological underpinnings of regulation are associated with all disease processes (Chrousos, 2009; Turner et al., 2020). In a cascading manner, less effective emotional and physiological responses to stressors can lead to prolonged and chronic use of more potent stress systems (e.g., the sympathetic-adrenal system) that result in disease and dysfunction (i.e., allostatic load; Danese & McEwen, 2012; McEwen & Morrison, 2013; McEwen &Wingfield, 2003; Miller et al., 2007;

Turner et al., 2020). As such, increasing scientific understanding of the factors that shape early regulatory processes is a critical task.

Infants are not passive recipients of external regulation and are biologically programmed to elicit responses from their caregivers and adapt to what their caregivers can offer (Cassidy, 1994; Schore, 2002). Developmental research has often focused on infant regulation capacities and strategies for managing distress and the caregiving correlates or synchronization of these processes (e.g., Feldman, 2012; Harrist & Waugh, 2002; Tronick, 2007). Although this work is important, it often neglects a central component of co-regulation: specifically, that effective regulation of another requires effective regulation of oneself (Moore et al., 2009). It is therefore essential to better understand how a mother prepares herself under conditions of dyadic stress. To address this aim, the present study investigated maternal variations in parasympathetic activity, a central physiological component of self-regulation, in relation to maternal caregiving behaviour, maternal symptoms of depression and anxiety, and infant distress.

This dissertation explores these facets of maternal regulation in the still face procedure (SFP; Tronick et al., 1978), a commonly employed dyadic stressor. The SFP is often used to assess infant regulatory responses, as the infant’s goal is clear: to reduce arousal, either by re-engaging their mother and/or by using underdeveloped self-regulation strategies (Adamson & Frick, 2003; Tronick, 2007). Despite the focus on infant responses, the SFP is also the ideal paradigm to examine variations in maternal self-regulation in the postpartum period. This procedure involves relational rupture and asks mothers to recover themselves and their infant, features common to the everyday challenges of parenthood (Feldman, 2007; Kemp et al., 2016; Tronick & Reck, 2009). Further, this procedure is differentially challenging to mothers depending on their historical relationship with their infant and their psychological and physiological resources for coping with the task's demands (Mesman et al., 2009; Tronick & Reck, 2009). Maternal parasympathetic activity is one index for assessing maternal physiological resources in this context and, as will be reviewed, is related to maternal psychopathology and caregiving behaviours. To date, most research has focused on maternal parasympathetic regulation in the SFP as a predictor of infant regulation or maternal caregiving behaviour. However, understanding what shapes and predicts maternal parasympathetic responsivity during dyadic stress is central to understanding the shared process of infant regulation.

Of the information available on this topic, most research examines only average differences in parasympathetic activity across episodes of the SFP (i.e., between baseline, the still face episode wherein the mother becomes unresponsive, and the reunion episode where the dyad attempts to recover). Yet, little is known about the dynamic ways that mothers physiologically respond to the temporal demands within the still face episode and reunion episode. Further, the literature is limited in terms of its assessment of how maternal caregiving, mood and anxiety interact to predict maternal parasympathetic capacities during dyadic stress and how these relate to the degree of infant distress in these episodes. As such, this dissertation aimed to examine: i) the dynamic trajectories of maternal parasympathetic regulation in both the still face episode and the reunion episode of the SFP; ii) the isolated and interactive effects of maternal emotional availability, maternal depressive symptoms, and maternal anxiety symptoms on these trajectories; and iii) their relation to infant distress levels in this dyadic context.

To ground the importance of this work, I first outline the critical nature of early caregiving environments on regulatory development. I introduce maternal emotional availability, maternal depression and maternal anxiety as factors that impact the mother-infant relationship and maternal self-regulatory processes. I then discuss the regulatory role of the parasympathetic nervous system and its measurement through the lens of Porges' (1995, 2001, 2007) polyvagal theory. This is followed by an examination of known patterns of parasympathetic dysregulation in individuals with mood and anxiety disorders. I then present what is known about maternal parasympathetic regulation in the context of the SFP and in other dyadic experimental stressors implemented across childhood. Based on the gaps uncovered in this review and the areas requiring further investigation, I outline the aims and hypotheses of this study. The remaining chapters present the methodology, results, and a discussion of the findings. Implications for this research are discussed in relation to future directions and public health applications.

Early Caregiving Environments and Regulatory Development

The importance of early caregiving environments on adaptive neurological, physiological, and psychological regulation cannot be overstated (Gunnar & Donzella, 2002; Gunnar & Quevedo, 2007; Loman & Gunnar, 2010; Sanchez et al., 2001). Evidence from quasi-experimental research of infants reared in obscene conditions of neglect demonstrates the long-term necessity of caregivers early in life, as the absence of early attachment relationships leads to lifelong cognitive, physical, social, and emotional difficulties (Mehta et al., 2009; Rutter et al., 2007). Analog evidence from animal studies further demonstrates the critical nature of caregiving relationships (Champagne & Meaney, 2001; Curley & Champagne, 2016; Howell et al., 2017). For example, cumulative evidence from studies assessing the effects of early isolation and maternal deprivation in primates show long-term modulation of neurological, physiological, behavioural, and emotional regulatory processes (as reviewed by Sanchez et al., 2001 and Sanchez et al., 2015). Primate studies examining peer-rearing (i.e., developing with same-age primates without caregivers) also show the importance of adult caregiving relationships, as peer-only bonds lead to similar multifactor dysregulation (e.g., Boyce et al., 1995). As argued elsewhere (Bernier et al., 2010; Caldji et al., 2000; Francis & Meaney, 1999), caregiving variants that exist outside of these ‘extreme’ or manufactured deprivation studies also lead to differing patterns of regulation associated with positive and negative biopsychosocial outcomes.

Quality of caregiving, particularly that delivered by mothers, is especially important during early development, or ‘sensitive periods’, where allostatic systems and neurobiology are most malleable to environmental variations (Curley & Champagne, 2016; Perry et al., 2017). One dimension of caregiving quality is maternal sensitivity, operationalized as the degree to which a mother responds to her infant’s cues in a manner that is loving, warm, contingent, and appropriate (Ainsworth et al., 1978). Definitions of maternal sensitivity differ in terms of scope depending on the measure or conceptualization in use (Bohr et al., 2018). Studies reviewed in this dissertation use a variety of sensitivity measures, which vary in their degree of construct overlap. For example, Bohr and colleagues (2018) compared four of the most commonly used sensitivity measures (i.e., the Ainsworth Maternal Sensitivity Scales, Emotional Availability Scales, Maternal Behaviour Q-sort, and the Nursing Child Assessment Satellite Training Feeding Scale) within the same 50 mother-infant interaction videos and found that sensitivity scores ranged in their degree of correlation from $r = .30$ to $r = .95$. The present study used the Emotional Availability Scales (EAS fourth edition; Biringen, 2008) to capture a broader view of sensitivity, which expands Ainsworth et al.’s attachment-based definition above to include an emphasis on genuine and appropriate emotional expressivity and responsiveness (Emde, 1980). In Bohr et al.’s (2018) study, the EAS and the Ainsworth Maternal Sensitivity Scales correlated at $r = .66$. Despite the variability in its measurement (Bohr et al., 2018), it is well-established that maternal sensitivity (or insensitivity) is a primary mechanism through which infants internalize regulatory processes (Sroufe, 1996; Stansbury & Gunnar, 1994). Further, variations in sensitivity (and its permutations) are associated with different infant autonomic, endocrine, and behavioural stress responses (Atkinson et al., 2013; Khoury et al., 2015; Laurent et al., 2012).

Paramount to the present study, sensitive caregiving (also referred to emotional availability herein) is contingent on maternal self-regulatory capacities. For instance, experiences or conditions that undermine maternal self-regulation have been linked to insensitive caregiving, including maternal depression (Barrett & Fleming, 2011; Field, 1994; Hakanen et al., 2019; discussed in more detail below), experiences of childhood maltreatment (Bödeker et al., 2019; Lyons-Ruth & Jacobvitz, 2008), and poorer executive functioning skills (Chico et al., 2014; Gonzalez, 2015; Johnston et al., 2012). Further, maternal sensitivity and maternal parasympathetic regulation are intertwined and likely mutually influencing. Appropriate reactivity and recovery of stress systems has been associated with subsequent positive caregiving behaviour in interactions with infants (Mills-Koonce et al., 2009; Sturge-Apple et al., 2011). Conversely, more sensitive mothers may cognitively appraise dyadic situations differently or have different goals in parenting contexts compared to less sensitive mothers (e.g., demonstrate more other-oriented, empathetic responses versus self-oriented, threat-processing responses; Leerkes et al., 2016); in turn, these differences may produce differing physiological reactions to dyadic stress (Moore et al., 2009). Thus, physiology may help mothers mobilize sensitive responses *and* sensitivity may influence the activation and recovery of physiological responses in different caregiving contexts. Although a bidirectional relationship is likely, the present study focuses on the latter; specifically, I examine how maternal emotional availability (measured over 30-minute observation period) relates to patterns of maternal parasympathetic functioning during a dyadic stressor administered two weeks subsequently.

In addition to maternal emotional availability, the present study examines the influence of two common and disruptive mental health concerns on maternal parasympathetic regulatory capacities, namely depression and anxiety. Prevalence estimates suggest that approximately 6.5% and 17.4% of women have a depressive or anxiety disorder during the perinatal period, respectively (Fairbrother et al., 2016). Furthermore, incidence estimates of these disorders suggest that the perinatal period is a risk factor for their development, with 5.8% and 6.1% of women developing depression or anxiety, respectively, in this period (Fairbrother et al., 2016). Research on the impact of depression and anxiety on the mother-infant relationship is based on clinical samples and dimensional examinations of symptomology (the latter approach is used in the current study). Symptoms of both conditions, even at subclinical levels, are associated with disruptions in the mother-infant relationship. Maternal depression, for example, has been framed as “emotional unavailability” and “contributes to dysregulation because the mother can no longer act as the optimal stimulator and arousal regulator for the infant” (Field, 1994, p. 208). Greater maternal depressive symptoms in the postpartum period disrupt dyadic regulation in several ways, including reductions in contingent responding, heightened focus on infant negative affect, less behavioural synchrony, and more intrusive behaviour (Cornish et al., 2008; Field, 1984; Field, 2010; Propper & Holochwost, 2013). Elevated maternal anxiety symptoms, commonly comorbid with depression (Fairbrother et al., 2016; Grigoriadis et al., 2019), are also related to dyadic disruption, including increased infant resistant attachment behaviour and negativity (Leerkes et al., 2011; Nolvi et al., 2016; Petzoldt et al., 2015), reduced mother-infant bonding (Tietz et al., 2014), and more intrusive parenting behaviour (Hakanen et al., 2019). These conditions are also associated with various forms of self-dysregulation across neurological, physiological, cognitive, and affective processes (e.g., Gotlib & Joorman, 2010, Grippo &

Johnson, 2009; Mennin et al., 2009; Sloan et al., 2017), all which may interfere with a mother's ability to appropriately function in the context of dyadic stress. The impact of depression and anxiety on the parasympathetic nervous system will be discussed in detail below.

In sum, early caregivers are essential components of regulatory development in the infant and normative variations in maternal caregiving, mood, and anxiety produce a range of dyadic and infant regulatory outcomes. Differences in these maternal factors may influence a range of maternal self-regulatory capacities, including maternal parasympathetic regulation. Understanding the relationships between these factors and maternal parasympathetic functioning is key to better understanding why some parents struggle more than others in alleviating dyadic stress while maintaining a strong connection.

The Parasympathetic Nervous System and Polyvagal Theory

The autonomic nervous system (ANS) is an essential component of the human regulatory system and involves separate and contrasting branches that work to achieve homeostasis. It involves the parasympathetic nervous system (PNS), the sympathetic nervous system (SNS) and the enteric nervous system (which controls the gastric and digestive tracts; Palumbo et al., 2007). Of specific interest to the present study is the role of the PNS, which maintains or reinstates homeostasis through negative feedback of the SNS and facilitates resting state functions (e.g., social engagement, growth, healing, excretion, and reproduction; McCorry, 2007; Porges, 1995). Parasympathetic regulation is often indexed as vagal tone (i.e., the activity of the vagus nerve). Vagal tone cannot be measured directly but can be estimated based on the relationship between heart rate and respiration. This is referred to as respiratory sinus arrhythmia (RSA)[1], which is calculated as beat-to-beat heart rate variability while accounting for respiration cycles (Bernston

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[1] Indexes of RSA are forms of assessing 'heart rate variability', which refers to a broader set of biomarkers associated with the ANS (Smith et al., 2020).

et al., 1997; Thayer et al., 2012). Increases in vagal tone (i.e., increases in RSA) are associated with regulatory, resting state functions (e.g., recovering from a stressor or being in a calm state), whereas decreases in vagal tone (i.e., RSA withdrawal) occur in response to threatening stimuli to engage active coping and facilitate operations of the SNS and other stress systems (e.g., the hypothalamic-pituitary-adrenal (HPA) axis; Del Giudice et al., 2011; Porges, 2007).

Porges' (1995, 2001, 2007; Porges et al., 1996) polyvagal theory proposes that humans (and mammals more broadly) are able to engage in social communication and self-soothing behaviour because of evolutionary developments in the ANS. In addition to the evolutionary preservation of older neural pathways responsible for physiological immobilization (the unmyelinated vagus nerve) and fight-and-flight responses (the sympathetic-adrenal system), mammals have developed a myelinated vagus nerve, which functions to more rapidly switch between states of calm and states of mobilization (i.e., cardiac activation). Flexibility in the 'switching' of this system, also referred to as control of the 'vagal break', is characteristic of adaptive and healthy circuitry (Porges, 2001, 2007; Porges et al., 1996). When flexibility is present, an individual can (unconsciously or consciously) increase vagal tone to promote a calmer, more socially engaged state (which enables positive affect, self-soothing behaviours, and approach behaviours) *and* appropriately decrease vagal tone to mobilize cardiac activity and efficiency of other stress systems (Porges, 2001). Reductions in vagal tone (i.e., RSA withdrawal) represent the first-line response to environmental challenges and stressors, which can be followed by responses from the more primitive systems, including the sympathetic-adrenal system, as necessary (Andrews et al., 2013; Del Giudice et al., 2011, Porges, 2001). A healthy vagal break can help protect against unnecessary activation of the other stress systems and the cumulative health costs associated with chronic use of these systems over time (i.e., allostatic load; McEwen and Wingfield, 2003). In comparison, less responsivity or lower basal vagal tone can indicate greater reliance on the sympathetic-adrenal pathway and greater engagement in emotional and behavioural responses consistent with a fight-flight-and-freeze state (Porges, 2001, 2007).

A body of work showcases individual differences in vagal tone. Cumulative evidence across the lifespan suggests that higher basal vagal tone and greater flexibility in the modulation of vagal tone during stress are associated with better behavioural and emotional regulation capacities and outcomes (Balzarotti et al., 2017; Bazhenova et al., 2001; Calkins, 1997; Calkins et al., 2013; Moore & Calkins, 2004). Individual factors, including symptoms of psychopathology, have also been linked to differing RSA profiles.

Parasympathetic Regulation and Psychopathology

RSA has been studied as a biomarker of psychopathology across the lifespan and across clinical and community samples (Beauchaine & Thayer, 2015). An extensive literature supports the relationship between low basal RSA and disorders of emotion dysregulation (as described by Beauchaine & Thayer, 2015; Koenig et al., 2016; Porges, 2007), including depression (Kemp et al., 2010), generalized anxiety disorder (Thayer et al., 1996), and borderline personality disorder (Koenig et al., 2015). Further, low basal RSA associates with transdiagnostic outcomes of emotion dysregulation, including suicide attempts (Tsypes et al., 2017) and non-suicidal self-injury (Crowell et al., 2005). Dysregulated RSA reactivity during challenge has also been linked to psychopathology, though there is greater variability in findings compared to those regarding basal profiles. Variability in these findings can be attributed to differences in the type of experimental stimuli applied (e.g., passive vs active tasks, emotion induction tasks vs cognitive tasks), type of psychopathology (e.g., internalizing vs externalizing), gender, and methodological features of RSA collection (Balzarotti et al., 2017; Beauchaine et al., 2019). For example, tasks that evoke negative emotions, compared to attentional, cognitive, or positive emotion induction tasks, are associated with greater RSA withdrawal in samples with greater externalizing disorder symptoms, but not for samples with greater symptoms of internalizing disorders or thought disorders (Beauchaine et al., 2019). Despite the variability in findings on this subject, two central forms of dysregulation in reactivity can be identified: i) difficulty mounting a response as needed, and ii) difficulty recovering the response as appropriate (Goldstein & McEwen, 2002; McEwen & Seeman, 1999). These features of RSA dysregulation will be discussed in relation to depression and anxiety, the two most common psychopathologies experienced postpartum.

According to Rottenberg (2005, 2007), there are two primary ways that depression can impact parasympathetic regulation as per the polyvagal theory. First, depression is associated with dysregulation in the social engagement system, including reductions in positive and adaptive social output and disruptions in the system's physiological underpinnings (e.g., lower basal RSA; Beauchaine, 2015; Beauchaine & Thayer, 2015, Rottenberg et al., 2007). These disruptions are intertwined and negatively cascading (e.g., lower physiological resources in social situations may make positive socialization harder; Rottenberg, 2007). Second, Rottenberg (2005, 2007) argued that depression is characterized by behavioural, emotional, and physiological inflexibility across contexts. These reductions in flexibility have been described as "emotional inertia", defined as "resistance to change, formalized as the degree to which a person's current emotional state can be predicted by the person's emotional state at the previous moment" (Kuppens et al., 2010, pg. 2). Individuals with depression often display blunted and delayed emotional and physiological responses to emotional stimuli but also remain in a negative mood state long after the stimulus is removed (Kuppens et al., 2010; Rottenberg, 2005;

Rottenberg et al., 2007). Thus, depression appears to impact an individual's timely response to environmental cues and their recovery once an eventual response is activated. In the context of parenting, these broader findings suggest that depressive symptoms may undermine a mother's parasympathetic flexibility during dyadic stress, in a way that may also interfere with her ability to mount appropriate caregiving responses.

Anxiety is also associated with parasympathetic dysfunction. Friedman (2007) and Friedman and Thayer (1998) emphasize autonomic inflexibility as a hallmark of anxiety in the autonomic flexibility—neurovisceral integration model. Whereas the pattern of inflexibility seen in depression can be described as inertia (Kuppens et al., 2010), the inflexibility that is characteristic of anxiety (both phasic and trait-like) lies in the cementation of fear-based processing, including hypervigilance to threat and over-activation of cardiovascular pathways. Specifically, anxiety is associated with lower cardiovascular control, including lower basal vagal tone and hyperarousal of the PNS (i.e., excessive RSA withdrawal) and SNS (i.e., excessive activation; Friedman, 2007; Friedman & Thayer, 1998). Individuals with anxiety show hyperarousal in the absence of acute environmental threat. For example, Levine and colleagues (2016) found that experimental induction of worry, the hallmark symptom of generalized anxiety disorder (GAD), was enough to produce RSA withdrawal in participants with GAD compared to control participants. Under conditions of experimental stress, however, individuals with anxiety do not consistently show differences in vagal tone compared to individuals with less anxiety or no anxiety disorder. That is, parasympathetic hyperarousal (i.e., exaggerated RSA withdrawal) does not necessarily translate to statistical differences when a paradigm is designed to elicit autonomic reactivity in participants. For example, Davis and colleagues (2002) did not find vagal tone differences across emotional induction, worry induction or attention tasks in undergraduate participants identified as worriers or non-worriers based on anxiety questionnaires. In sum, anxiety associates with parasympathetic inflexibility, but not necessarily in the same manner as depression.

Complicating matters is the fact that anxiety and depression often co-exist (e.g., Brown et al., 2001; Fairbrother et al., 2016). This overlap has been cited as a possible reason for the mixed RSA reactivity findings in the literature (Friedman, 2007; Rottenberg, 2007). Comorbidity between depression and anxiety is often the rule rather than the exception, and there is ongoing debate about whether these syndromes are distinct entities or exist along the same spectrum of pathology (Brown & Barlow, 2005). Factor analyses of these diagnoses support their distinction but also show high correlations between them (Brown et al., 1998). Clark and Watson's (1991) tripartite model of anxiety and depression attempts to account for both aspects of this debate by suggesting that anxiety and depression share negative affect as a common factor, but anxiety is distinctly associated with hyperarousal of stress systems, whereas depression is distinguished by anhedonia (consistent with discussions of emotional inertia above). Further, Friedman (2007) and Rottenberg (2007) have suggested that anxiety may moderate autonomic reactivity in individuals with depression, suggesting that anxiety may lower vagal tone in these individuals. Although these theories are based on patterns in the literature, the evidence is mixed. As mentioned above, anxiety is not consistently associated with hyperarousal (e.g., Davis et al., 2002). Furthermore, studies have found the same pattern of dysregulation, specifically, blunted RSA reactivity and slow recovery, in women with pure GAD, pure major depressive disorder, and both syndromes (Kirchanski et al., 2016). Inconsistencies across studies point to the need for further investigation across contexts and the need to examine anxiety as it exists alone and in combination with depression. With regards to parenting, these findings suggest that anxiety may associate with different patterns of parasympathetic dysregulation during dyadic stress depending on depressive comorbidity.

Maternal Parasympathetic Regulation During Dyadic Stress

As reviewed, polyvagal theory and related research indicates that flexibility in the PNS helps individuals engage socially and assists with appropriate physiological mobilization in the context of environmental challenge and recovery as the challenge dissipates or is managed. These features of parasympathetic regulation are important in general situations but are also adaptive in the context of parenting, with its ongoing and variable demands. Theoretically, flexibility in the PNS would permit social engagement in the mother-infant relationship and appropriate shifts to physiological mobilization as needed in the context of dyadic stress. This section outlines what is currently known about maternal parasympathetic regulation in experimental paradigms, beginning with induction of dyadic stress in early infancy and extending to later development.

Examining Dyadic Stress in Early Infancy: Use of the Still Face Procedure

As described in first paragraphs of this dissertation, the SFP (Tronick et al., 1978) is widely used to evoke dyadic multisystem regulatory responses in the first year of life. In this procedure, mothers and infants sit face-to-face and interact for a short baseline period (typically 2 to 3 minutes). The mother then engages in a 2-minute emotional separation from her infant by enacting a ‘still’, unresponsive face, which violates infant expectancies of typical reciprocity. Because infants are so reliant on their caregivers, this threat to their relationship is enough to reliably produce the ‘still face effect’, characterized by decreases in positive affect and increases in negative affect and averted gaze (Mesman et al., 2009). Following this disruption, dyads re-engage in the reunion episode, wherein the mother attempts to repair the relationship and soothe her infant. This separation and reunion process activates the attachment system (similar to the strange situation procedure used in later infancy) and draws out mother and infant responses that represent historical interactions and developing working models[2] (Braungart-Rieker et al., 2014; Miller et al., 2002; Tronick, 2003; Weinberg & Tronick, 1996).

Historically, research employing the SFP has focused on infant regulation, with the bulk of studies focusing on infant responses to and recovery from the still face episode and the factors that influence these responses. Multiple meta-analyses have determined patterns of infant regulation. Mesman and colleagues (2009) found strong evidence for the 'still face effect' and its partial persistence into the reunion episode. Maternal sensitivity (measured before or during the SFP) significantly moderated this effect, with infants of more sensitive mothers showing more positive affect during the still face episode. Maternal depression, however, produced mixed results, with some studies showing decreased infant distress, diminished gaze and less interactive behaviour, and other studies finding increased infant distress or no differences. Mesman and colleagues speculated that these differences may be the result of a moderating effect of sensitivity on the relationship between depressive symptoms and infant responses, and/or the presence of comorbid conditions. Regarding infant physiological regulation, a meta-analysis by Shahrestani et al. (2014) found a significant pattern of infant RSA withdrawal in the still face episode compared to baseline and RSA increase during reunion that returned to baseline levels. This finding was replicated in a more recent meta-analysis by Jones-Mason and colleagues (2018). These authors also found that infant RSA recovery in the reunion was stratified by

[2] Note that infant attachment cannot be reliability classified until around 12 months of age, at which point infants are said to have developed "internal working models" of how their parent will respond under different emotional and contextual conditions (Bowlby, 1969; Braungart-Rieker et al., 2014, though evidence for working models has been questioned, see Atkinson et al., 2000). Thus, interactions and working models assessed within the first year represent *processes in development*, rather than established patterns (Braungart-Rieker et al., 2014).

socioeconomic status, such that infants of families with greater socioeconomic challenge had less recovery in this episode. The SFP is also known to evoke infant stress responses in the SNS (Ham & Tronick, 2006) and HPA-axis (Haley & Stansbury, 2003).

Despite the plethora of studies on infant regulation in the SFP, its impact on maternal regulation is less often examined. In part, this may be due to the common framing of this task as an infant stressor. Yet, the SFP is also challenging to parents. The still face episode, for instance, asks mothers to be the source of their infant's distress, which runs counter to most caregiving intentions. The still face episode may be less potent than the reunion episode, however, because the instructions permit some level of dissociation on the mother's part (Busuito et al., 2019). In comparison, the reunion episode requires active attempts to soothe the infant, repair the relationship and self-regulate, making it the most challenging episode to caregivers (Ham & Tronick, 2006). Compounding these tasks are the mother's awareness that she is being filmed and observed (akin to the social-evaluative component prominent in adult experimental stressors; Dickerson & Kemeny, 2004). Within both episodes, the demands on mothers may differ across time. For example, the first portion of the still face episode may be less stressful than the last half when infant distress reliably increases (Mesman et al., 2009). Similarly, the reunion may only be challenging until the relationship is repaired, which may occur more rapidly in some dyads. The level of challenge that a mother experiences across these episodes likely depends on the history of the mother-infant relationship and the psychological and physiological resources the mother has available for the task (Musser et al., 2012). Of concern to the present dissertation are patterns of dynamic maternal parasympathetic regulation in the SFP and associations with maternal factors that may impact flexible regulation within these episodes.

Maternal Parasympathetic Regulation during the Still Face Procedure

Only a handful of studies have focused on understanding and predicting maternal parasympathetic regulation in the SFP. Of those assessing maternal RSA as the outcome variable, most examine mean changes across episodes (Busuito et al., 2019; Feldman et al., 2010; Ham & Tronick, 2006; Moore et al., 2009). To my knowledge, only two studies assess the dynamic maternal RSA changes that occur within these episodes (Oppenheimer et al., 2013; Ostlund et al., 2017). The most consistent pattern of RSA responses across these studies is an increase in average maternal RSA in the still face episode (Moore et al., 2009; Oppenheimer et al., 2013) and a decrease in the reunion episode (Busuito et al., 2019; Moore et al., 2009). However, evidence is mixed, with some studies finding no significant differences between episodes (Feldman et al., 2010), others finding differences within episodes when assessed dynamically (Oppenheimer et al., 2013; Ostlund et al., 2017) and others finding differences in patterns depending on maternal and dyadic factors (Ham & Tronick, 2006; Moore et al., 2009).

With regards to the still face episode, investigators have argued that mean maternal RSA increases (compared to baseline) are the result of lower interactive demands required of mothers during this episode (Busuito et al., 2019; Moore et al., 2009). Yet, theory implies that infant distress is activating for mothers (Goldberg et al., 1999; Leerkes, 2010) and parallel findings in cry-response paradigms show maternal RSA reactivity during the presentation of infant distress (discussed in more detail below; e.g., Ablow et al., 2013; Joosen et al., 2013). The inconsistency between theory and data may be due to the reliance on examining maternal RSA as an average within this episode, rather than examining the dynamic changes that may be occurring over time. Results from Oppenheimer et al. (2013) provide strong evidence for this argument. They examined maternal RSA in the still face episode in both an average and dynamic fashion in a sample of 81 mother-infant dyads (oversampled for maternal depressive symptoms). When maternal RSA was examined as an average, it was found to increase from the baseline episode to the still face episode. Maternal depressive symptoms, their predictor of interest, was not related to average maternal RSA response in the still face episode. However, they found a different pattern of results when examining maternal RSA trajectories (in 10 second epochs across the still face episode). In this set of analyses, the mean RSA linear trajectory was not significantly different from zero, though it varied significantly between individuals. Variance in these trajectories was best explained by an interaction between maternal depressive symptoms and infant distress levels. Specifically, mothers with high levels of maternal depressive symptoms had RSA increases in the context of increasing infant distress, whereas mothers with low depressive symptoms showed RSA suppression in this context (consistent with mobilizing for active coping). This dynamic analysis of physiology provides a more nuanced account of maternal RSA activity during dyadic stress and its relation to maternal depression.

Of note, Oppenheimer and colleagues (2013) also assessed the impact of maternal anxiety symptoms on maternal RSA trajectories. They did not find statistical evidence for a relationship between anxiety and maternal RSA in isolation or in interaction with infant distress. However, the main effect and interactional effects of anxiety followed the same directional trends as maternal depressive symptoms. The authors recommended that researchers continue to examine the relationship between maternal anxiety symptoms and maternal RSA during dyadic stress continue to be examined.

Regarding patterns of maternal parasympathetic responding in the reunion episode, there is a general assumption that decreases in maternal RSA are preferable and correspond to mobilization of active coping to soothe the infant (Mills-Koonce et al., 2007; Moore et al., 2009).

In support of this argument, Moore and colleagues (2009) found that maternal sensitivity (rated in a free play interaction separate from the SFP) predicted RSA withdrawal in the reunion episode. Mothers with the highest levels of sensitivity (+1 standard deviation in their sample) showed mean RSA withdrawal (difference score from baseline level) compared to mothers at other levels of sensitivity. In addition, they found that mothers who were more behaviourally synchronous with their infant during the SFP showed lower RSA in the reunion episode, as did mothers with infants who displayed more negative affect. Likewise, Busuito and colleagues (2019) reported a general finding of maternal RSA decline in the reunion episode. Interestingly, however, they found that mothers with less behavioural synchrony with their infant had the lowest levels of mean RSA across all episodes of the SFP. This finding may be more illustrative of the importance of parasympathetic flexibility and may highlight the importance of assessing dynamic changes in RSA trajectories.

Relatively little is known about dynamic maternal RSA changes in the reunion episode. Ostlund and colleagues (2017) are the only authors (to my knowledge) to provide some report of maternal RSA changes in this episode. They assessed mother-infant vagal synchrony in the reunion episode of the SFP. Their procedure involved a truncated reunion episode that lasted for one minute (rather than the typical two minutes). They computed RSA in five second epochs and analyzed the first 30 seconds of the reunion separately from the last 30 seconds. Mother-infant physiological synchrony was the primary outcome of this study, so isolated differences in maternal RSA growth were obscured in the results. Nevertheless, their dynamic assessment of physiology revealed the importance of assessing trajectories across time. Within the first portion of the reunion, the authors found that maternal RSA increased, on average, and that this coincided with decreases in infant RSA. In the last 30 seconds, they found that maternal RSA decreased while infant RSA increased, although this synchrony was non-significant. The authors also found that mothers with higher anxiety symptoms had higher RSA in the second half of the reunion, as compared to the first half. Maternal depressive symptoms did not emerge as a significant predictor in these models. These results illustrate the complexity of maternal physiology in this episode and the dynamic ways that RSA may change in relation to infant factors and maternal factors. This dissertation aims to further unpack these reunion trajectories.

Despite the limited number of studies focused on the nuances of maternal parasympathetic regulation in the SFP, there is a growing body of research that underscores the importance of this factor. For example, some studies have assessed maternal RSA as it relates to infant recovery in the reunion episode. Ham and Tronick (2006) reasoned that maternal RSA reductions in the reunion were preferable because infants of mothers with this profile had the greatest affective recovery in this episode. In comparison, mothers who showed RSA increases in the reunion had infants who did not recover emotionally. Other studies have assessed the long-term outcomes associated with maternal RSA in the SFP. Groh and colleagues (2019) administered the SFP at infant age 6 months and the strange situation procedure at 12 months. They found that the degree of maternal RSA withdrawal in the reunion episode of the SFP (compared to baseline) was associated with infant attachment behaviour at 12 months. Specifically, they found that mothers with less RSA withdrawal in the reunion were more likely to have infants with avoidant attachment behaviour in the strange situation procedure. In a similar procedure, Mills-Koonce and colleagues (2007) found a significant three-way interaction between maternal sensitivity, infant negative affect and maternal RSA withdrawal measured during the SFP (infant age 6 months), but only in dyads where the infant was later classified as avoidant in the strange situation procedure (administered at age 12 months). Specifically, they found that limited RSA withdrawal in the context of greater infant distress was associated with less sensitive behaviours in mothers of avoidant infants.

Additionally, maternal RSA has been assessed as a predictor (or mediator) of maternal behaviour during the SFP. Leerkes and colleagues (2016), for example, assessed maternal RSA regulation and maternal sensitivity during three consecutive infant stressors (the SFP, an arm restraint and a novel toy approach). Maternal RSA regulation (defined as a decrease in RSA from baseline) did not have a significant main effect on sensitive behaviour during these distressing contexts. However, maternal RSA regulation was indirectly associated with sensitivity through maternal attributions of their infant's distress, as measured during a cry-processing interview that immediately followed the stressors. Mothers who displayed greater RSA suppression during the tasks tended to engage in less self-focused and negative attributions of infant cries and this in turn predicted greater sensitivity. Mills-Koonce and colleagues (2009) found that mothers with higher cortisol levels displayed higher levels of intrusive parenting behaviour in the SFP reunion episode, but greater RSA withdrawal attenuated this relationship and served as a protective parenting factor for these mothers. Musser and colleagues (2012) assessed baseline levels of maternal RSA and maternal depressive symptoms on maternal sensitivity in the still face episode. Lower basal RSA was related to less sensitive parenting, as was higher maternal depressive symptoms, although no interaction between RSA and depression emerged. Collectively, these results support the notion that parasympathetic regulation relates to maternal capacity for sensitive caregiving.

The findings reviewed in this section are presented in Table 1. In summary, there is limited research on maternal parasympathetic regulation in the SFP despite consistent agreement that maternal physiological regulation is an important component of predicting maternal behaviour and infant regulation. As mentioned previously, the relation between maternal RSA and caregiving behaviour is bidirectional. Yet, rarely is maternal RSA assessed as the outcome variable and there is little understanding of how maternal factors (e.g., sensitivity, depression, anxiety) are related to RSA trajectories. The research on maternal factors is equivocal and under-replicated. Moreover, the work that is available often assesses mean episodic changes, which can oversimplify the dynamic individual and dyadic changes that occur during each segment.

Table 1

Summary of Studies Assessing Maternal RSA in the Still Face Procedure

Study	*N* dyads	Infant age in months	RSA Modelling	RSA as Outcome?*	Predictor variables*	Still Face Procedure Findings*		
						Across Episodes	Still Face Episode	Reunion Episode
Busuito et al., 2019	140	6	Mean change	Yes	Behavioural synchrony	Less synchronous mothers have the lowest RSA across episodes	Maternal RSA increases on average	Maternal RSA withdrawal on average
Feldman et al., 2010	53	6	Mean change	Yes	Maternal touch	RSA not sig. different across episodes	Greater RSA withdrawal in no-touch condition	
Groh et al., 2019	127	SFP: 6 SSP: 12	Mean change	No; attachment at 12 months in SSP	Maternal sensitivity (NICHD system), maternal RSA, maternal affect			Less maternal RSA withdrawal during reunion episode related to greater infant avoidant behaviour at 12 months
Ham & Tronick, 2006	12	5	Mean change	Yes	Infant affective recovery status		Mothers of infants who affectively recovered or were non-reactive show increases in RSA	Mothers of recovered/non-reactive infants show decreases in RSA
Leerkes et al., 2016	259	6 (and 12 months)	Mean change	No; maternal sensitivity (own coding system)	Maternal RSA; maternal cry processing responses	Maternal RSA not directly related to sensitivity; maternal RSA withdrawal indirectly predicts sensitivity via less self-focused/ negative cry processing		

Study	*N* dyads	Infant age in months	RSA Modelling	RSA as Outcome?*	Predictor variables*	Still Face Procedure Findings* Across Episodes	Still Face Episode	Reunion Episode
Mills-Koonce et al., 2007	148	SFP: 6 SSP: 12	Mean change	No; maternal sensitivity (NICHD system)	Maternal RSA, infant negative affect, infant attachment	Less maternal RSA withdrawal during infant distress associated with less sensitive parenting, for avoidant dyads only		
Mills-Koonce et al., 2009	175	6	Mean change	No; maternal intrusiveness and positive engagement	Maternal RSA, maternal cortisol, infant negative affect	No main effects of maternal RSA on parenting behaviour	No sig. maternal RSA findings observed	High maternal cortisol predicted greater intrusiveness, but greater RSA withdrawal attenuated this effect
Moore et al., 2009	152	6	Mean change	Yes	Maternal sensitivity (NICHD system); behavioural synchrony, infant negative affect		Maternal RSA increases on average	Greater sensitivity, behavioural synchrony, and infant negative affect all independently associated with greater maternal RSA withdrawal

Study	*N* dyads	Infant age in months	RSA Modelling	RSA as Outcome?*	Predictor variables*	Still Face Procedure Findings* Across Episodes	Still Face Episode	Reunion Episode
Musser et al., 2012	89	5	Basal RSA	No; maternal sensitivity (Global Coding Scheme)	Maternal basal RSA; maternal depressive symptoms (EPDS)			Lower basal RSA and depressive symptoms independently associated insensitivity in the reunion; no sig. interaction
Oppenheimer et al., 2013	81	5	Dynamic	Yes	Maternal depressive symptoms (CES-D), maternal anxiety symptoms[ǂ] (BAI)		Greater depressive symptoms associated with limited RSA withdrawal in context of infant distress; no sig. effect of anxiety	
Ostlund et al., 2017	95	6-8.5	Dynamic	Partially; RSA attunement	Maternal anxiety symptoms (BAI), maternal depressive symptoms (EPDS)			First 30 sec., maternal RSA increases as infant RSA decreases; Last 30 sec., greater maternal anxiety associated with increasing maternal RSA; No main effect of depression

Note. *predictor, outcome variables and findings are only provided for results that pertained to maternal RSA measured in the still face procedure. Studies often contained other hypotheses and findings, but these additional results are not reported in this table.

BAI = Beck Anxiety Inventory; CES-D = Centre for Epidemiologic Studies Depression Scale; EPDS = Edinburgh Postnatal Depression Scale; NICHD = National Institute of Child Health and Human Development; RSA = respiratory sinus arrhythmia; SFP = still face procedure; SSP = strange situation procedure

Maternal Parasympathetic Regulation in Other Dyadic Stress Tasks

Although research on maternal parasympathetic regulation in the SFP is limited, there is adjacent research on maternal physiology in other parent-child experimental stressors. Findings from these studies provide additional context for what is known about how maternal factors influence maternal physiological regulation during dyadic stress.

The cry-response task is an experimental paradigm that most closely resembles what mothers experience during the still face episode. Within this task, mothers are typically asked to listen to and/or watch clips of an infant crying. In a sample of 53 pregnant women, Ablow and colleagues (2013) assessed maternal physiological responses (RSA, heart rate and skin conductance level) during two infant cry videos (one where the infant was visible and one where they were not) and their relation to maternal attachment classifications on the Adult Attachment Interview. There were no basal differences in RSA between classifications, but reactivity in these systems differed during the cry tasks; mothers classified as secure-autonomous had decreasing RSA during the task while mothers classified as insecure-dismissing showed increasing RSA (and increasing skin conductance). Mothers classified as insecure-dismissing also reported higher levels of aversion to the infant cry tapes, which, in combination with their physiological profiles, the authors understood as evidence of behavioural inhibition during stress. Joosen and colleagues (2013) assessed maternal physiology during three blocks of audio crying and how this related to maternal sensitivity (assessed during free play without toys and bath time with their toddlers). They found that more sensitive mothers displayed greater decreases in RSA during the first block of infant crying compared to less sensitive mothers. Meanwhile, less sensitive mothers had lower, flatter RSA responses throughout the paradigm, suggesting a less flexible response. Results from these studies suggest that maternal RSA withdrawal in response to acute infant distress may be adaptive for mounting a caregiving response, and that flat or increasing RSA in these situations may relate to non-optimal responses.

Maternal RSA responses have also been measured in the strange situation procedure, a task involving a series of separation and reunion episodes with infants between 12 and 24 months (Ainsworth et al., 1978). This paradigm is similar to the SFP in that it disrupts dyadic responding and permits observation of dyadic responses to this rupture and the subsequent reunion. However, it exceeds the emotional separation of the SFP by instructing mothers to leave the room while their infant tolerates their separation in the presence of a stranger and alone. Hill-Soderlund and colleagues (2008) assessed mean maternal RSA (and salivary alpha-amylase) during each episode of the strange situation procedure. All mothers showed mean RSA withdrawal (compared to baseline) during the separation episodes, where they watched their infant behind a one-way mirror. There were no differences in RSA in the separation episodes between mothers of securely attached infants and infants with insecure attachments. However, mothers of secure infants had greater RSA withdrawal during the final reunion compared to mothers of insecure infants. In another study assessing maternal physiology during the strange situation procedure (153 dyads), Sturge-Apple and colleagues (2011) computed sympathetic-parasympathetic ratios of arousal during each episode. It is not possible to draw equivalence between SNS-PNS ratios and RSA patterns alone, though generally speaking a high ratio would indicate high SNS arousal and low RSA. The authors found that mothers with greater depressive symptoms showed a hyperarousal response across the task (i.e., higher SNS activity and lower RSA), and this group was more likely to demonstrate harsh and intrusive parenting behaviour during free play. Moderate levels of maternal reactivity were predictive of more sensitive parenting (though it is difficult to determine the isolated patterns of SNS versus RSA within this moderate range). These results suggest that mothers with greater depressive symptoms showed less flexibility in the PNS and greater reliance on the sympathetic system. The findings from these two studies are somewhat discrepant, perhaps due to differences in computing RSA (in isolation versus as a ratio). Yet, differences may also point to an interaction between maternal depressive symptoms and maternal caregiving behaviours that was not directly analyzed.

Beyond infancy, maternal RSA has also been examined in puzzle tasks and cleanup tasks with young children. These tasks do not involve separations or reunions but still require dyadic navigation of frustration. For example, puzzle tasks are typically selected to be above the child's developmental abilities and clean-up tasks involve navigating a goal that the child may not share. These tasks may be fun and challenging for some dyads or stressful and disruptive for others depending on maternal and relational factors. Lunkenheimer and colleagues (2017) examined differences in mother and child (mean age 3.5 years) RSA during a puzzle task, clean up task and free play session. Relevant to the present dissertation, maternal depressive symptoms were related to greater declines in RSA across the puzzle task and clean up task, which the authors interpreted as evidence that these mothers found these tasks more stressful than mothers with less depressive symptoms. In another study with children of the same age, Miller and colleagues (2015) found that mothers with higher RSA during a puzzle task showed less negativity towards their child, in line with polyvagal theory (i.e., higher RSA facilitates positive social engagement). They also found that lower RSA combined with higher SNS activation (which they termed sympathetic dominance) was associated with harsh parenting during an origami building task. Collectively, these results illustrate the importance of assessing RSA in context. While RSA withdrawal may be appropriate during acute stress (e.g., during the first block of a cry paradigm, during separation), it is not preferable when social engagement is the goal. These studies also provide further evidence that maternal physiological regulation during dyadic challenge associates with maternal mood and with maternal caregiving behaviour.

One puzzle task study examined the role of maternal anxiety on physiological co-regulation (Borelli et al., 2018). Although the authors of this study reported child RSA, they only reported on heart rate for mothers, thus the findings relate to ANS activity rather than PNS regulation specifically. Borelli and colleagues did not find evidence of differing maternal HR across the puzzle challenge with respect to maternal anxiety levels. However, they did find that mothers with higher anxiety who exhibited more parental overcontrol during the puzzle task had less prominent increases in heart rate across the task. The authors argue that parental overcontrol may serve a regulatory avoidance strategy for mothers with high anxiety. In other words, mothers may exert control over their child's behaviour to reduce their feelings of physiological reactivity. Although these findings do not directly inform understanding of maternal parasympathetic regulation, they do point to a potential interaction between maternal caregiving, maternal anxiety, and maternal autonomic reactivity during dyadic stress. In the still face episode of the SFP, maternal control is removed, and so greater autonomic reactivity may accompany higher anxiety in this situation.

With respect to dyadic stressors with older children and adolescents, maternal parasympathetic regulation has been assessed during conflict discussion tasks. In these tasks, dyads are instructed to discuss a recent conflict or area of friction within the relationship (e.g., screen use, homework completion, household chores). McKillop and Connell (2018) found evidence for the impact of maternal depression on maternal physiological inertia (Kuppens et al., 2010) in a sample of 59 mother-adolescent dyads. They found that mothers with higher depressive symptoms had RSA profiles that were slower to return to baseline throughout the conflict discussion task. Of note, profiles were assessed in an actor-partner dependence model so slow return to baseline was defined in relation to the change from the previous epoch. Nevertheless, these results are consistent with theory that depression impairs parasympathetic flexibility, which the authors outline as a potential mechanism contributing to problematic parent-child interactions. In a similar study, Amole and colleagues (2017) compared differences in RSA between dyads where both mothers and adolescent daughters had histories of major depression (*n* = 23) and dyads with no history of depression (*n* = 23). Dyads without depression showed positive RSA synchrony during pleasant and conflict discussions, with increasing RSA in both situations (compared to adjacent rest periods). In comparison, dyads with depression displayed flat RSA profiles across the situations, and negative synchrony (e.g., if maternal RSA increased, adolescent RSA decreased). Other studies using the conflict task have focused specifically on parent-child parasympathetic synchrony (Suveg et al., 2019; Woody et al., 2016) and find that maternal depressive symptoms relate to negative dyadic RSA synchrony during conflict discussions. Woltering and colleagues (2015) did not examine maternal depression but found that mother-child dyads who were physiologically in sync during a conflict discussion were better able to behaviourally repair their relationship afterwards. In all, the studies examining parasympathetic regulation during parent-child conflict further show the importance of regulation during dyadic stress. Further, these studies provide additional evidence that maternal depressive symptoms may dampen RSA flexibility and that this dampening may interfere with dyadic regulation.

The literature on maternal parasympathetic regulation during other dyadic stressors points to a few overarching themes. First, that maternal RSA responses should be assessed in context, because activation or withdrawal are both adaptive depending on circumstance. For example, it may be appropriate to show RSA withdrawal in acute distress (e.g., during infant distress in the context of a separation) but not when the task may benefit from positive social engagement or is not acutely stressful. Second, these studies highlight the importance of flexibility in the PNS, as appropriate modulation of RSA occurs more often in less depressed and more sensitive mothers. In comparison, flat RSA trajectories across contexts or slow recovery to baseline occurs more often in mothers with greater depressive symptoms and less sensitive responses. Third, these studies underscore the importance of self-regulation in contexts where co-regulation is the goal. Across findings, the more adaptive physiological profiles were the ones that aligned with contextual dyadic needs. For example, when positive social communication was helpful (e.g., when discussing a contentious topic, to assist a child with preserving through a challenging puzzle), more sensitive or less depressed mothers were able to maintain higher parasympathetic activity (consistent with polyvagal theory). Mothers with the same characteristics also displayed RSA withdrawal during acute stress where mobilization of stress systems may be more adaptive. Thus, contextually appropriate maternal parasympathetic regulation appears to be an adaptive component of parenting across development.

Notably, none of the studies reviewed assessed the influence of maternal anxiety symptoms on maternal parasympathetic regulation in other dyadic stressors. The study reviewed by Borelli and colleagues (2018) on maternal heart rate in the puzzle challenge task stood alone in this respect. Further, the above studies rarely assessed maternal depressive symptoms and caregiving behaviour in interaction, and never in models with maternal RSA as the outcome. These continue to be areas requiring further investigation.

The Current Study

As reviewed, research on maternal parasympathetic regulation during dyadic distress in infancy is limited and variable in terms of methodology, intention, and analytical approach. This dissertation aims to clarify and improve the available literature by: i) probing dynamic maternal parasympathetic responses (in contrast to analyses of average vagal responses within episodes); ii) more fully exploiting and examining the different regulatory demands of the still face episode and the reunion episode; iii) and more thoroughly examining the independent and interactive effects of infant distress, maternal emotional availability, maternal depressive symptoms and maternal anxiety symptoms on dynamic maternal parasympathetic regulation within these episodes. Based on the differing task demands within each episode, distinct hypotheses were forwarded for each segment. Table 2 summarizes these hypotheses in a distilled format.

Still Face Episode Hypotheses

Hypothesis 1: *Maternal RSA trajectories in the still face episode relate to maternal depressive symptoms and infant distress. Specifically, mothers with more depressive symptoms show less decrease in RSA in the context of greater infant distress compared to mothers with fewer depressive symptoms.* This hypothesis is consistent with Oppenheimer et al.'s (2013) findings and with the literature showing impaired flexibility to environmental cues, particularly negative stimuli, in individuals with depression.

Although not a formal hypothesis in the statistical sense, I do not expect maternal anxiety to emerge as a significant predictor of maternal RSA in isolation or in interaction with infant distress (as per null findings in Oppenheimer et al., 2013). As per the following hypothesis, I expect maternal anxiety to only emerge when considered in interaction with maternal depressive symptoms.

Hypothesis 2: *Maternal depressive symptoms and anxiety symptoms interact with infant distress to predict maternal RSA. Mothers with greater depressive symptoms show less decrease in RSA than mothers with fewer depressive symptoms during greater infant distress, regardless of anxiety level. However, when depressive symptoms are low, mothers with greater anxiety symptoms show hyperarousal (i.e., greater RSA withdrawal) compared to mothers with fewer depressive and anxiety symptoms.* The predicted interaction between depression and anxiety is based on the consistency of inflexibility findings in the depression literature and the unique features of anxiety outlined in the tripartite model of anxiety and depression (Clark & Watson, 1991). Further, mothers with more anxiety symptoms (and less depressive symptoms) may be particularly reactive to their infant's distress because their ability to exert control in this episode is limited (as per findings in Borelli et al., 2018).

Hypothesis 3: *More emotionally available mothers respond to increasing infant distress with greater RSA withdrawal compared to less emotionally available mothers*. Although previous work has not found a significant influence of maternal sensitivity on average levels of maternal RSA in the still face episode (e.g., Moore et al., 2009), the influence of emotional availability may emerge when maternal RSA is assessed dynamically. Similar to mothers with less depressive symptoms (Oppenheimer et al., 2013), physiological mobilization is expected to help mothers with greater emotional availability prepare for the task of soothing their infant.

Hypothesis 4: *Mothers with greater emotional availability and fewer depressive symptoms show greater RSA withdrawal in the context of increasing infant distress compared to mothers with more depressive symptoms and less emotional availability*. Given that there is limited information in the literature on the interaction between maternal emotional availability and maternal anxiety on maternal RSA, I compute this interaction for exploratory reasons without expectations. Likewise, I took the same approach for the three-way interaction between maternal emotional availability, depressive symptoms, and anxiety symptoms.

Reunion Episode Hypotheses

Hypothesis 5a: *In the first half of the reunion episode, mothers with greater depressive symptoms show higher levels of RSA compared to mothers with fewer depressive symptoms.* The first portion of the reunion episode tasks mothers with re-engaging their infants. Mothers with fewer depressive symptoms are expected to show physiological activation (i.e., RSA withdrawal) during this task consistent with mobilizing an appropriate caregiving response. In comparison, mothers with greater depressive symptoms will show delayed physiological activation during this portion of the reunion episode.

Hypothesis 5b: *In the second half of the reunion episode, mothers with greater depressive symptoms show steeper RSA declines compared to mothers with fewer depressive symptoms.* Mothers with greater depressive symptoms are expected to find the reunion episode more challenging than mothers with fewer depressive symptoms. While mothers with fewer depressive symptoms may be able to shift towards physiological recovery in the last portion of the reunion, mothers with greater depressive symptoms are expected to demonstrate decreases in RSA (i.e., prolonged stress response).

Hypothesis 6: *In the second half of the reunion episode, mothers with greater anxiety symptoms and fewer depressive symptoms show greater recovery (i.e., slower declines) compared to mothers with less anxiety symptoms and more depressive symptoms.* This hypothesis is based on the results from Ostlund and colleagues (2017), who found that mothers had greater RSA recovery during the latter portion of the reunion episode.

Hypothesis 7a: *Mothers with greater emotional availability show lower RSA in the first portion of the reunion episode compared to mothers with less emotional availability.* In a similar study, Moore and colleagues (2009) had forwarded two potential hypotheses about the relationship of maternal sensitivity on average maternal RSA in the reunion. They predicted that sensitive mothers would either show: a) heightened RSA withdrawal in the reunion to support their re-engagement efforts; or b) less cumulative RSA withdrawal because of their greater likelihood of efficiently soothing their infants. Ultimately, they found evidence for their first hypothesis, with more sensitive mothers presenting the greatest RSA withdrawal. However, it is conceivable that average examinations of RSA in the reunion obfuscated the possibility that *both* predictions are true. Thus, part (a) of this hypothesis predicts that mothers with greater emotional availability will display greater RSA withdrawal than mothers with less emotional availability to support their re-engagement efforts.

Hypothesis 7b: *Mothers with greater emotional availability show slower declines in RSA in the last portion of the reunion compared to mothers with less emotional availability.* As per Moore et al.'s (2009) second hypothesis, I expect that mothers with greater emotional availability will slow their RSA withdrawal (i.e., begin physiological recovery) in the latter portion of the reunion compared to mothers with less emotional availability.

Hypothesis 8a: *Mothers with greater depressive symptoms and low emotional availability show limited RSA withdrawal in the first portion of the reunion episode compared to mothers with fewer depressive symptoms and high emotional availability.* The reunion episode is considered the most challenging phase of the still face procedure for parents (Ham & Tronick, 2006). I expect that mothers with greater depressive symptoms and less emotional availability will have the greatest difficulty physiologically preparing themselves during the first portion of the reunion, when re-engagement is prioritized.

Hypothesis 8b: *Mothers with greater depressive symptoms and low emotional availability show greater RSA declines in the latter portion of the reunion episode compared to mothers with fewer depressive symptoms and high emotional availability.* Considering their expected challenges with the re-engagement demands at the start of the reunion, mothers with more depressive symptoms and less emotional availability are not expected to enter physiological recovery as they will still be immersed in a stressful experience. By comparison, it is expected that less depressed mothers with greater emotional availability will have the most success with re-engaging their infant in a way that permits physiological recovery to a regulatory state associated with positive social engagement (Porges, 2007).

Table 2

Study Hypotheses in a Simplified Format

Hypothesis	Depressive Symptoms	Anxiety Symptoms	Emotional Availability	Infant Distress	Comparative RSA Trajectory
Still Face Episode					
1	↑			↑*	Lack of withdrawal
2	↑	↕		↑*	Lack of withdrawal
	↓	↑		↑*	Hyper-withdrawal
3			↑	↑*	Appropriate withdrawal
4	↓		↑	↑*	Appropriate withdrawal
Reunion Episode					
5a	↑				Lack of withdrawal
5b	↑				Lack of recovery
6	↓	↑			Appropriate recovery
7a			↑		Appropriate withdrawal
7b			↑		Appropriate recovery
8a	↑		↓		Lack of withdrawal
8b	↑		↓		Lack of recovery

Note. This table simplifies the study hypotheses by presenting the expected RSA trajectory for one dimensional side of the predictor variable. For example, hypothesis 1 refers to the expected RSA trajectory for mothers with greater depressive symptoms in the context of greater infant distress *as it compares to* mothers with fewer depressive symptoms in this same context.

* indicates that this value does not change in the comparative hypothesis

a – refers to the first half of the reunion episode, where re-engagement is the task

b – refers to the last half of the reunion episode, where recovery is the task

CHAPTER 2: Method

Power Analysis

As detailed below, the planned analyses use multilevel modeling techniques to best estimate the trajectories of maternal RSA in the still face and reunion episodes. For heuristic purposes, I derived a rough power estimate to approximate the sample size required to address the proposed aims, substituting multiple regression for the more advanced multilevel application (as power calculations for these models are complex and imperfect). The power analysis was conducted using *G*Power 3.1* (Faul et al., 2009). I estimated a model with four predictors (i.e., maternal emotional availability, maternal depressive symptoms, maternal anxiety symptoms, infant distress), power set to .80, and alpha set to .01 to account for multiple analyses. A conservative effect size of $f^2 = .15$ (as per Cohen's 1988 guidelines) was used because of limited effect size reporting in the small literature on sensitivity, mood, and anxiety on maternal parasympathetic regulation, and because available effects are often in the small-to-medium range (e.g., Busuito et al., 2019; Moore et al., 2009). Based on this input, a sample of 82 mother-infant dyads was required. Recruitment efforts for the larger longitudinal sample were based on power analyses for differing questions and considered attrition rates for varying dyadic methodologies (e.g., neurological data loss in infant populations as in Cristia et al., 2013). However, the results from this power analysis indicate that a sample of 82 dyads would permit exploration of the forwarded hypotheses. This sample size is a reasonable estimate because: a) it does not include nested variance that is accounted for in multilevel applications; and b) studies with similar hypotheses display sample sizes within a comparable range ($N = 81$ in Oppenheimer et al., 2013; $N = 95$ in Ostlund et al., 2017).

Participants

Ethics approval for this study was granted by the Ryerson University Research Ethics Board. A community sample of mother-infant dyads living in Toronto, Ontario was recruited via flyers, social media posts, and presentations at community centres, infant classes, and infant trade shows as part of a longitudinal project following children from age 6-months to 18-months. Recruitment efforts attempted to capture a range of risk in early environments (e.g., posting and attending events across neighbourhoods representing various socioeconomic distributions). Dyads were eligible to participate if the mother was at least 18 years old at the time of participation, dyads had no major physical illness (as this can confound dysregulation in physiological systems; Rees, 2014), and mothers were sufficiently fluent in English to respond to questionnaires. Infants were excluded if they were born low birthweight (i.e., born weighing less than 2500 grams; United Nations Children's Fund & World Health Organization, 2004), as regulation may differ systematically in this population (Feldman, 2006; Fuertes et al., 2011). Infants who were born preterm (i.e., before 37 weeks gestation; American College of Obstetricians and Gynecologists, 2013) were included if they were of normal birthweight.

This dissertation utilized data from the first two (of a possible four) participant visits embedded in the larger study. The two visits used here were scheduled between infant ages 6-months and 8-months. The mean number of days between the first and second visit was 13.10 (*IQR* = 11.00). Attempts were made to schedule these visits within two weeks of each other, although flexibility was permitted to account for maternal convenience and other factors (e.g., infant illness). The first study visit took place at participant homes for maternal convenience, while the second visit took place at Ryerson University to provide access to the necessary equipment used in the experimental stressor. To be included in the present analyses, dyads had to participate in the first visit and have useable maternal RSA data available for the experimental stressor portion of the laboratory visit. A total of 128 mother-infant dyads consented and participated in the first study visit. Two dyads dropped out after the first visit. An additional ten dyads either opted out (*n* = 7) or aged out (*n* = 3) of the second visit held at the laboratory. Seven dyads had laboratory visits scheduled that were disrupted by COVID-19 (which halted all data collection beginning mid-March 2020). Thus, 109 dyads attended a laboratory visit. Ten dyads did not complete the experimental stressor due to infant distress that was not resolved by taking breaks, feeding, or engaging in other troubleshooting suggestions. Two additional dyads had unusable still face procedures; in one case, the experimenter interrupted the procedure due to a safety concern, and in the other, the experimenter prematurely terminated the still face episode before the 20 second infant distress limit. Fourteen mothers had unusable ECG data in at least one of the still face episodes due to excessive movement artefacts. The final sample included 83 mother-infant dyads. There were no significant differences among demographic variables between dyads in the final sample compared to all dyads who participated in visit 1, as outlined in Table 3. Further, there were no significant differences between the between-subjects variables of interest (i.e., emotional availability, depressive or anxiety symptoms) as depicted in Table 4.

Table 3

Comparisons Between Dyads in the Final Sample and those Excluded from the Final Sample on Demographic Characteristics

	Dyads Excluded from Final Sample			Dyads in the Final Sample				
Variable	*N*	*M*	*SD*	*N*	*M*	*SD*	*t(df)*	*p*
Maternal Age	44	33.75	4.75	83	33.67	4.21	.09 (125)	.927
Family Income Level (before taxes)	41	9.63	2.47	81	9.81	1.86	-0.45 (120)	.651
	N	*M*	*SD*	*N*	*M*	*SD*	χ^2 *(df)*	*p*
Racial/Ethnic Identity (dichotomous)	45	0.49	0.51	83	0.40	0.49	1.07(1)	.319
Marital Status (dichotomous)	45	0.11	0.32	83	0.08	0.28	0.25 (1)	.620
Education Level (dichotomous)	45	0.02	0.15	83	0.08	0.28	1.92(1)	.166

Note. Dyads in the final sample had maternal RSA available for each episode of the still face procedure. Demographic data were dichotomized for the purpose of comparison, as there were limited participants in several demographic factor subgroupings. Racial and ethnic identity was dichotomized as individuals identifying as White compared to individuals identifying as Black, Indigenous or Person of Colour. Marital status was dichotomized as married or common-law status compared to single, widowed, divorced or not-common-law relationship. Education level was dichotomized as individuals with post-secondary education versus secondary education or less.

Table 4

Comparisons Between Dyads in the Final Sample and those Excluded from the Final Sample on Between Subject Variables of Interest

	Dyads Excluded from Final Sample			Dyads in the Final Sample				
Variable	*N*	*M*	*SD*	*N*	*M*	*SD*	*t(df)*	*p*
Maternal EAS Composite Scores	45	78.28	17.11	83	81.26	18.05	-0.91(126)	.365
PSWQ Total Scores	45	46.47	14.54	83	48.17	12.78	-0.69(126)	.494
	N	*Median*	*IQR*	*N*	*Median*	*IQR*	*U*	*p*
EPDS Total Scores	45	6.00	7.50	83	7.00	6.00	1846.00	.914

Note. Dyads in the final sample had maternal RSA available for each episode of the still face procedure. EAS = Emotional Availability Scales; EPDS = Edinburgh Postnatal Depression Scale; PSWQ = Penn State Worry Questionnaire. Depressive symptoms were positively skewed, and so non-parametric data and tests are presented for this variable.

Participant Demographics

In the final sample, maternal age ranged from 25 to 44 years (*M* = 33.67, *SD* = 4.21). Infant age at visit 1 ranged from 5.88 months to 7.92 months (*M* = 6.63, *SD* = 0.54), and at visit 2 ranged from 6.11 months to 8.15 months (*M* = 7.06, *SD* = 0.60). Most mothers had completed some post-secondary education (91.60%) and reported being married or in a common-law relationship (91.60%). Demographic information is detailed in Table 5, including maternal racial and ethnic identity, family income before tax, housing status, infant biological sex, and percentage of infants with siblings.

Table 5

Demographic Characteristics of the Final Sample (N = 83)

	Percentage
Maternal Education	
Secondary or less	8.40%
College	14.50%
Bachelor’s Degree	38.60%
Post-Graduate Degree	38.60%
Maternal Racial/Ethnic Identity	
European/White	60.20%
Asian	13.30%
East or West Indian	10.80%
Biracial/ Multiracial	8.40%
Hispanic / Latina	4.80%
Black	2.40%
Married or Common-Law	91.60%
Family Income Range Before Tax	
Below $20,000	2.40%
$20,001 - $25,000	1.20%
$25,001 - $35,000	0.00%
$35,001 - $50,000	2.40%
$50,001 - $75,000	16.90%
$75,001 - $100,000	13.30%
$100,001 - $150,000	28.90%
$150,001 - $200,000	14.50%
$200,001 - $250,000	12.00%
More than $250,001	6.00%
Housing Situation	
Renting / Leasing	32.50%
Homeowner	61.40%
Other (e.g., living with family, living in a shelter)	6.00%
Female Infants	41.00%
% of infants with siblings	25.30%

Experimental Stressor – The Still Face Procedure (SFP)

Dyadic stress was induced using the the SFP (Tronick et al., 1978), a laboratory paradigm used to assess infant and dyadic regulatory processes by perturbing reciprocal responding, thereby activating the attachment system in a manner influenced by historical experiences of availability and regulation (Kogan & Carter, 1996; Miller et al., 2002; Weinberg & Tronick, 1996). Following typical SFP procedures, dyads were asked to engage in the following three sequential episodes: 1) a 3-minute baseline (or free-play) episode involving normal face-to-face interaction without toys; 2) a 2-minute still face episode, wherein mothers disengaged from the interaction by applying a neutral, non-expressive gaze towards their infant (coupled instructions to abstain from vocalizations and touching the infant); and 3) a 2-minute reunion episode wherein mothers attempted to re-engage their infant. For ethical purposes, the still face and reunion episodes were terminated early if the infant cried hard and persistently for 20 seconds.

Measures

Demographic Information

A background questionnaire was developed to obtain self-reported demographic information. Mothers reported on their own demographic information, as well as their partner's when relevant (for use in the larger longitudinal study). Mothers were also asked questions to probe the socioeconomic status of their family of origin during their own childhood, the data of which are not relevant for the present study. Mothers completed this demographic form at visit 1 (see Appendix A).

Maternal Depression

The Edinburgh Postnatal Depression Scale (EPDS; Cox et al., 1987) was used to assess levels of maternal depressive symptoms within the past seven days. The EPDS focuses on the cognitive and emotional symptoms of depression rather than the somatic symptoms that commonly overlap with typical maternal experiences postpartum (Cox et al., 1987). Ten items, each ranging in value from 0 to 3, comprise this self-report measure. The total score has a possible range of 0 to 30, with higher scores corresponding to greater depressive symptoms.

There is ample evidence to support the reliability and validity of the EPDS throughout gestation and up to two years post-partum (Gibson et al., 2009; Kozinszky & Dudas, 2015). The present study found strong internal consistency (Cronbach's $\alpha = .86$), which is consistent with the literature (Cronbach's $\alpha \geq .80$; e.g., Cox et al., 1987; Da Costa et al., 2000). The English version EPDS demonstrates high test-retest reliability within two days of administration (ICC = .92; Kernot et al., 2015). Research on the test-retest reliability of the English version beyond this time period is limited but has been demonstrated over two- and three-week periods in a Chinese translation (ICC = .85; Wang et al., 2009) and Norwegian translation (ICC = .74; Eberhard-Gran et al., 2001), respectively. Validation studies using diagnostic clinical interviews (i.e., the Structured Clinical Interview for DSM-IV) demonstrate satisfactory concurrent validity with diagnoses of depression (Navarro et al., 2007). Convergent validity has been established with other self-report measures of depression including the first and second version of the Beck Depression Inventory (correlations ranging from $r = .79$ to 82; Beck & Gable, 2001; e Couto et al., 2015; McCabe-Beane et al., 2016). Negative correlations have also been found with measures of maternal self-reported confidence ($r = -.33$) and easygoing personality styles ($r = -.25$; Da Costa et al., 2000). The EPDS often significantly correlates with measures of perinatal anxiety (e.g., Matthey et al., 2013), consistent with the diagnostic overlap between these two conditions (Brown & Barlow, 2005; Clark & Watson, 1991). In the present sample, these measures correlated at $r = .68$, indicating both shared and unique variance between them.

Maternal Anxiety

The Penn State Worry Questionnaire (PSWQ; Meyer et al., 1990) was administered to assess symptoms of maternal anxiety. The PSWQ is a 16-item self-report measure that probes aspects of pervasive worry, the central construct associated with generalized anxiety disorder (Meyer et al., 1990). Items are ranked along a five-point Likert scale that corresponds to whether a statement is or is not very typical of the respondent. Total scores range from 16 to 80, with higher scores associated with greater anxiety. The original validation of the PSWQ found strong internal consistency across several samples ($\alpha \geq .90$; Meyer et al., 1990), and subsequent research has established reliability in the perinatal period (Blackmore et al., 2016; Swanson et al., 2011). High internal reliability was found in the present sample (Cronbach's $\alpha = .93$).

Scores on the PSWQ show validity with clinically diagnosed anxiety disorders, particularly generalized anxiety disorder (Brown et al., 1992). The PSWQ also discriminates from measures of OCD (Brown et al., 1992). The PSWQ has been found to correlate with measures of maternal depression in perinatal samples (e.g., $r = .53$ with EDPS in a postpartum sample; Swanson et al., 2011). As mentioned above, this relationship between the PSWQ and EDPS is consistent with symptomatic overlap between these constructs (Brown & Barlow, 2005; Clark & Watson, 1991). As such, neither the PSWQ or EDPS is a "pure" measure of these psychological phenomena, nor could they be given current diagnostic understanding. The difficulty distinguishing between these phenomena is not simply a measurement problem, but rather reflective of human functioning. Beyond their overlapping features, however, both measures capture unique components of anxiety and depression and, when assessed in interaction, they provide a dimensional ratio of these symptoms within an individual.

Maternal Emotional Availability

Quality of maternal caregiving was assessed with the Emotional Availability Scales, Fourth Edition (EAS; Biringen, 2008). The EAS comprises six scales that map on to different elements of dyadic communication, regulation, and responsiveness (Biringen et al., 2014). Four of these scales pertain to maternal behaviours: sensitivity, structuring, non-intrusiveness, and non-hostility. Two additional scales pertain to the child's behaviour in the relationship: the child's involvement of the caregiver in play/interactions (child involvement scale) and how responsive the child is to their caregiver (child responsiveness scale). The child scales were not used in this study as the focus was on maternal behaviour. Each emotional availability scale was assigned a total score that ranged from 7 to 29 points[3]. Higher total scores are associated with more optimal caregiving behaviour. For example, a higher score on the sensitivity subscale would correspond to greater evidence that a mother displayed reciprocal and appropriate affect, perceived and responded to her infant's signals in a timely manner, interacted in a kind and accepting way, and could effectively manage conflict, spontaneous play and the dynamic attentional demands within the environment (Biringen, 2008; Biringen et al., 2000). Similarly, a mother scoring highly on the other scales would be non-intrusive, non-hostile, and able to set appropriate limits while emotionally supporting and scaffolding autonomous behaviour.

As reviewed by Biringen and colleagues (2014), the EAS shows convergent validity with other measures of attachment and sensitivity (e.g., Ainsworth's Attachment Q-Sort), and displays

[3] Each emotional availability score was also assigned a direct score (ranging from 1 to 7) that summarized the overall quality of the dimension, relying most heavily on the two primary subscales comprising each scale. For example, the sensitivity direct score was most strongly influenced by a mother's affective quality and clarity of perceptions. The interrater reliability coefficients for these direct scales were as follows: ICC = .75 for sensitivity, .54 for structuring, .67 for non-intrusiveness, and .71 for non-hostility. Mothers were also assigned a categorical zone reflecting the overall quality of their relationship to their infant. These zones (i.e., emotionally available, complicated, avoidant, and problematic) are theoretically akin to attachment classifications. However, they have not yet been individually validated and attachment classifications are typically not assigned until infant age 12 months. As such, these zones are not reported in this dissertation.

short-term stability in infancy and toddlerhood (e.g., Bornstein et al., 2006; Howes & Obregon, 2009). For instance, composite EAS scores (using the EAS fourth edition) showed strong and increasing stability (standardized coefficients ranging from .45 to .60) across four observations during infancy (2, 4, 6 and 12 months; Pillai Riddell et al., 2011). Regarding construct validity, the four adult EAS scales strongly resemble the multiple scales that are used in Ainsworth's sensitivity scales to generate a single sensitivity value (Biringen et al., 2014). Other studies have shown the emotional availability scales load onto a single factor (Wiefel et al., 2005), and use a composite of these scales as a result (e.g., Fonagy et al., 2016; Pillai Riddell et al., 2011; Wiefel et al., 2005). In the present sample, there was considerable overlap in total scores across the four adult scales (correlations ranging from r = .64 to .90).

Certification on the EAS coding system was obtained via online training and supervision with the scale's developer (Z.Biringen). Within-lab interrater reliability was achieved by double-coding randomly selected videos until a minimum level of agreement was met (80% of subscales within 1-point difference). Final codes for double-coded videos were derived via discussion by the two certified coders. From that point, 25% of videos (21 of the final 83 tapes) were randomly double-coded. Subscales that were discrepant by more than 1-point were discussed in group supervision and a final code was determined. The intraclass correlations[4] between rater total scores in the final sample fell in the moderate range across scales: .77 for sensitivity, .64 for structuring, .67 for non-intrusiveness, and .70 for non-hostility. After submitting reliability scores, coders were encouraged to bring difficult videos to group supervision, and several were watched and assigned a final code in this context.

[4] Intraclass correlations were derived using a two-way random effect model (absolute agreement definition). Single measure intraclass correlations are reported (c.f., average measure intraclass correlation).

Infant Distress Coding

Infant affect was coded at one-second intervals (all milliseconds set to .000) across the still face procedure. The original coding scheme utilized a seven-point scale ranging from expressions and vocalizations that represented the most distressed states (e.g., upset crying, upset screaming, highly distressed facial expressions) to the most positive states (e.g., laughing, happy/delighted screams, pronounced positive vocalization). A non-determinable code was used in cases where an infant's face was obscured to the level that a code would have been assigned at random. Raters could code an obscured face if the associated audio and adjacent frames provided enough context to confidently ascertain the infant's affect. This scale was developed based on previous studies examining infant emotion regulation in the SFP (Haley & Stansbury, 2003; Kogan & Carter, 1996, Lowe et al., 2012). Codes from this seven-point scale were converted to a five-point distress scale following the work of Oppenheimer et al. (2013). In this five-point scale, the three original positive affect scores were merged into a single positive score (value of 0), followed by neutral expressions (value of 1), milder expressions of discomfort (e.g., frowns, whimpers; value of 2), more prominent expressions of anger, discomfort, or sadness (value of 3), to expressions and vocalizations denoting high levels of distress (e.g., screaming, crying; value of 4). Appendix B features the detailed infant affect coding scheme.

Infant affect was coded using BORIS, an open-source event-logging software (Friard & Gamba, 2016). An independent rater coded all SFP tapes for infant affect after being trained and developing sufficient reliability with the author (B. Jamieson). After obtaining interrater reliability, 22% of tapes from the final sample were double-coded. The average ICC on the five-point scale for these tapes was .77 (*SD* =.15). Final codes for reliability tapes were discussed in weekly supervision and assigned final codes in this context.

Respiratory Sinus Arrhythmia Acquisition and Data Preparation

Maternal heart rate was derived from electrocardiograph (ECG) waveforms that were recorded using Biopac's BioNomadix Dual Wireless Respiration and ECG Module, which interfaced with Biopac's MP150 Data Acquisition System (BIOPAC Systems, Inc., Goleta, CA, USA). Prior to commencing the SFP, three disposable electrodes (BIOPAC Systems Inc., general purpose electrodes) were appropriately covered in electrode gel (Signa brand) and placed on the mother's chest in the following positions: one on her right collarbone and one below each ribcage (see Appendix C for diagram). The ECG signal was sampled at a rate of 2000 samples per second during the procedure and later processed using Acqknowledge 5.0 with scripting capacity (BIOPAC Systems, Inc., Goleta, CA, USA). Each individual ECG waveform was subjected to a bandpass filter (using Blackman -61 dB windowing), with a low frequency cutoff of 1 Hz and a high frequency cutoff of 35 Hz. The software identified QRS complexes (i.e., heartbeat cycles) across the waveform and a script was used to isolate the R-wave peaks, as R-to-R intervals are the most relevant to RSA extraction. Tachograms were used to identify problematic heartbeats within the waveform. Missing or spurious heartbeats were manually corrected (i.e., replaced with the mean heartbeat between adjacent R-wave peaks). To be included in the final sample, the number of manual heartbeat corrections could not exceed 10% (Holochwost et al., 2014; Mills-Koonce et al., 2009; Moore et al., 2009; Qu & Leerkes, 2018). Within the final 83 maternal waveforms, the average number of manual artefact insertions was 1.13% (*SD* = 1.14%).

Maternal RSA was computed in 10 second epochs[5] in each of the SFP episodes (following Oppenheimer et al., 2013). Spectral analysis[6] was used to extract variations in spectral power in the high frequency band (set as .15 to .40 Hz; Shader et al., 2018). RSA is reported as the natural logarithm of high frequency power in milliseconds squared. Baseline RSA was calculated by averaging all epochs in the 3-minute baseline (free play) episode. In the still face and reunion episodes, epochs were examined as trajectories to permit dynamic understanding of maternal physiology in these segments.

Potential Covariates

Potential covariates of maternal RSA were collected and accounted for in the statistical models, as necessary. Brief descriptions of these covariates are presented below.

Demographic Characteristics

Age has been intermittently associated with heart rate variability and RSA. Methodologically, it is known that specific RSA band frequencies are required for different age groups (i.e., between infants and adults; Shader et al., 2018). Yet, there is inconsistent evidence on the impact of age on RSA across adulthood. For example, in their meta-analysis of RSA and psychopathology, Beauchaine et al. (2019) found no moderating effect of age (M = 30.53, SD = 7.75). However, in a mother-infant SFP study, Busuito and colleagues (2019) found that maternal age significantly correlated with RSA values across SFP episodes, with lower RSA

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[5] Basal estimates of RSA recommend upwards of 5-minutes of consistent ECG collection (Task Force of the European Society of Cardiology the North American Society of Pacing Electrophysiology, 1996). However, epochs as short as 5 to 10 seconds have been used to reliably study reactivity in the parasympathetic nervous system (Huffman et al., 1998; Oppenheimer et al., 2013; Ostlund et al., 2017).
[6] Spectral analysis uses pre-programmed estimations of respiratory cycles. There are other available methods for extracting RSA. For example, the peak-and-valley method uses an individual's respiration data to extract heart rate variations (Grossman et al., 1990). Maternal respiration was collected in this study but suffered from movement artefacts. It is less feasible to correct movement artefacts in respiration data compared to ECG data. Regardless, different methods for extracting RSA are highly correlated and used interchangeably throughout the literature (Goedhart et al., 2007; Grossman et al., 1990).

found among older mothers compared to younger mothers (age in sample: M = 32.00, SD = 1.70). They also found that the main effect of episode (i.e., differences between the baseline episode, still face episode and reunion) was reduced to a non-significant level when accounting for maternal age. Given the similar, yet less restricted, age range in the present sample (M = 33.67, SD = 4.21) maternal age was examined as a possible covariate.

Studies on adult heart rate variability also occasionally assess the impact of other demographic factors, such as race and education status. Education status emerged as a significant covariate in Busuito and colleague's (2019) study, with mothers with higher educational attainment showing less heart rate arousal. Racial status (coded as the percentage of Caucasian participants) was not significant in Beauchaine et al.'s (2019) meta-analysis. Theoretically, differences in educational attainment, racial identity and income may relate to changes in stress physiology because of the high allostatic load associated with poverty, racism, and systematic oppression (Pascoe & Richman, 2009; Sturge-Apple et al., 2011). The root causes of systematic chronic stress were not assessed in this study and so these demographic factors were included as proxy covariates.

Maternal Antidepressant Use

Studies examining adult psychopathology and RSA (or heart rate variability more broadly) have found mixed evidence on the influence of antidepressants on features of RSA. The use of tricyclic antidepressants has been consistently associated with lower basal RSA (Kemp et al., 2010; van Zyl et al., 2008), whereas the impact of Selective Serotonin Reuptake Inhibitors (SSRIs) is less consistent (Kemp et al., 2010; van Zyl et al., 2008). A large depression cohort study in the Netherlands (N = 2,373) found that antidepressant use (including SSRIs) accounted for the relationship between depression and lower basal heart rate variability (Licht et al., 2008).

This finding was also replicated in a study of older adults with depression (O'Regan et al., 2015). In comparison, a meta-analysis found that SSRI use did not mitigate the relationship between depression and lower basal RSA (Kemp et al., 2010). However, this meta-analysis has been criticized for not including adults with cardiovascular disease, which led to the exclusion of the Netherlands study (Licht et al., 2011). Even so, unmedicated adults with depression also show lower basal RSA (Kemp et al., 2012). Lack of assessment of antidepressant use may account for some of the error in studies examining RSA and psychopathology (Beauchaine et al., 2019). As such, data on maternal use of antidepressants were collected in the present study, though only three mothers reported taking SSRIs (out of 78 mothers who answered this question). The RSA episode values for these mothers were assessed visually.

Maternal Still Face Manipulation Check

As qualitatively noted by Tronick and colleagues (1978), mothers "found it difficult to sit still-faced in front of the infant" (pg. 10). Thus, each still face episode was subjected to a manipulation check to determine the consistency of the procedure across dyads (Toda & Fogel, 1993). Maternal expression was coded at one-second intervals (using BORIS software, milliseconds set to .000) as either intact (i.e., neutral or negative non-reciprocal expression) or divergent (i.e., a noticeable reciprocal facial expression). Maternal vocalizations and touches[7] were also coded as divergent frames, as these can create differences in physiological and behavioural regulation (Feldman et al., 2010). These codes were assigned by an independent rater who was blind to study hypotheses. 20% of these tapes were double-coded, with an average percentage agreement of 98.06% (agreement ranged from 90.36% to 100%). Across the still face

[7] Maternal touch most often occurred in the context of mothers quickly adjusting the infant's physiological equipment for safety purposes (e.g., removing the functional near infrared spectroscopy headband if it fell over the infant's eyes).

episode, most frames contained an intact still face (*M* = 96.33%, *SD* = 5.71%), consistent with task instructions. Across participants, the percentage of divergent frames ranged from 0% to 33%. Following procedures used by Toda & Fogel (1993), mothers who engaged in more than 15 seconds of divergent behaviour were compared to mothers below this level in a paired samples t-test, with infant distress as the outcome. Only four mothers had divergent levels above this cut-off. Infants of these mothers had significantly higher distress (*M* = 3.05, *SD* = 0.73) compared to all other infants (*M* = 2.10, *SD* = 0.81) suggesting that higher levels of divergence did not impact the potency of the stressor. There were also no significant correlations between the percentage of divergent frames and the outcome variable or any other variables of interest (i.e., maternal emotional availability, maternal depressive symptoms, maternal anxiety symptoms) correlations ranged from $r = -.17$ to .15, $p = .14$ to .83).

Procedure

Procedures relevant to the first and second visits are described here, although additional visits were performed as part of the larger longitudinal study. All first and second visits were completed between infant age 6 to 8 months, with visit times and dates scheduled according to maternal preference. Prior to scheduling the first visit, participants completed a preliminary phone screen to ensure they met inclusion criteria. Two research assistants attended the first visit at participant homes and completed informed consent procedures with mothers prior to collecting data. Following consent, the visit involved the following three components: i) completion of maternal questionnaires; ii) completion of a 30-minute filmed interaction between mothers and infants; and iii) a standardized storytelling procedure (for use in the larger longitudinal project). The mother-infant interaction was divided into three segments to mimic real-world conditions. Across all conditions, mothers were instructed to ‘be themselves with their infant’. In the first

10-minutes, mothers were tasked with completing questionnaires (on an iPad), as a means of dividing maternal attention in a manner consistent with naturalistic caregiving demands (Pederson et al., 1990). In the following 10-minute period, mothers and infants interacted with toys provided by the research team (a ball, a car, a Vtech play phone, and a Vtech drum with five blocks that fit into corresponding openings). In the final 10-minutes, dyads were asked to be together without any toys, which induced an unstructured and, for some families, a more challenging form of interaction. Interactions were paused at maternal request. At the end of the visit, mothers were compensated for their time and effort and were reminded about what to expect at their second scheduled visit.

The second visit took place in the laboratory at Ryerson University. This visit involved four components: i) a dyadic experimental stressor, the SFP (Tronick et al., 1978); ii) a filmed 30-minute interaction (same as the first visit); iii) maternal completion of questionnaires (most often finished during the filmed interaction); and iv) collection of height and weight from infants and mothers (for use in the longitudinal project). The experimental stressor was completed first to maximize the time that infants were awake. Mothers were informed of the steps involved in the SFP and were given time to ask questions and resolve concerns. Mothers were also encouraged to feed and change their infants prior to the stressor to ensure a base level of contentment before beginning. Prior to the stressor, mothers and infants were connected to several pieces of physiological technology to collect stress system biomarkers (all products of BIOPAC Systems, Inc.). These included electrodes for capturing skin conductance and heart rate, and a band to monitor respiration. Mothers also wore a transducer to measure pulse. Infants, when tolerant, also wore a functional near infrared spectroscopy headband to measure neural activity. Only maternal heart rate data were analyzed and reported in this dissertation[8]. Technology was fastened as efficiently and calmly as possible to minimize dyad distress. After all the infant gear was applied, mothers were asked to put their infants into a gender-neutral sleeper outfit (provided by the experimenters or brought by mothers according to communicated guidelines[9]), to minimize infant access to the cords and reduce coder-related gender bias (as in Conradt & Ablow, 2010; Ostlund et al., 2017).

Once all equipment was secured (except the spectroscopy headband which was placed last), infants were placed in a highchair facing their mothers who were seated in a chair (approximately 50 cm away). Instructions for the SFP were posted on the wall within the mother's view. Mothers were asked to limit their physical movement to avoid physiological artefacts (e.g., refrain from clapping). The task began only when infants appeared calm and/or were distracted. The SFP involved a 3-minute free play episode (no toys), a 2-minute still face episode (wherein mothers disengaged from any physical or vocal interaction with their infant while applying a neutral, expressionless gaze), and a 2-minute reunion. Research assistants observed the stressor behind a one-way mirror and cued each episode by knocking on the mirror. The experimenter did not proceed into the still face episode if the infant was crying in distress. In these cases, the experimenter would end the task and provide opportunities for the mother to soothe the infant (e.g., via feeding, physical connection, a short break walking around the lab) before restarting. Still face and reunion episodes were terminated if an infant cried persistently for 20 seconds. When still face episodes were terminated early, the dyad proceeded to the

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[8] Other physiological data collected from mothers and infants were not assessed. There were difficulties with movement that reduced the usability of these measurements in a large portion of dyads.

[9] Mothers were given the option to use a gender-neutral coloured infant sleeper provided by the experimenters or to bring their own from home. Colours that were avoided were blue, pink, and purple. In cases where sleepers brought from home did not meet these colour criteria (or did not have clasps to allow the wires to feed through), lab-provided sleepers were used instead.

reunion episode. The entirety of the stressor was dual-videotaped, with one camera positioned on the mother and another on the infant. Input from these cameras was simultaneously recorded into a single video file. Once the stressor was complete, the research assistants removed the physiological equipment and provided the dyad with time and space before moving them into the 30-minute interaction (done in a separate playroom). The 30-minute interaction was filmed with ceiling cameras, such that dyads were left alone to interact within the same segmented structure as conducted in the home. These videos were not coded for the purposes of this dissertation, as the home videos were selected to best represent the naturalistic parent-infant relationship[10]. Once the interaction and height and weight procedures concluded, mothers were thanked for their time and provided remuneration.

Data Preparation and Analytic Approach

All relevant study variables were assessed visually and statistically for outliers. In the case of questionnaire data, EAS scores and infant distress codes, this procedure was conducted to ensure accurate data entry (i.e., all data points within the appropriate range). Maternal RSA outliers were assessed across epochs in the still face episode and the reunion episode separately. Where possible, artefacts were addressed in the raw data to mitigate the issue. Epoch values that fell outside of ± 3 standard deviations from the episode mean were winsorized (to the closest 3SD value; Jones et al., 2019). In the still face episode, a total of eight epochs from four participants fell beyond the ± 3 standard deviation episode range (-1.32 to 5.82 $\ln(ms)^2$). In the reunion episode, only two epochs from two participants fell outside the ± 3 standard deviation range (-1.22 to 5.38 $\ln(ms)^2$). Winsorized values were used in all subsequent analyses.

[10] These data may be used in a future study to assess interaction stability over time.

Preliminary analyses were conducted to understand the study sample, the relationships between the variables of interest, and the influence of potential covariates on the outcome variable (maternal RSA). Bivariate correlations were run between demographic factors and study variables, and between potential covariates and the outcome variable. Covariates that significantly correlated with the outcome variable were explored in the advanced models. Further, as described previously, a factor analysis was conducted to determine whether maternal EAS scores should be assessed as a composite variable or as four separate scales. As described in the results section, the use of a continuous EAS composite was justified.

A multilevel modelling (MLM) approach (Raudenbush et al., 2011; Singer & Willet, 2003) was used to investigate all study hypotheses. MLM was the most appropriate analytical choice for several reasons. 1) Physiology collected across time points is naturally nested within individuals. That is, it is likely that one person's RSA value at one epoch is more closely related to their RSA at another epoch than another random person's RSA at any epoch. MLM accounts for nested data that are otherwise neglected or attributed to error in other statistical models (Curran et al., 2010; Raudenbush et al., 2011; Singer & Willet, 2003). 2) MLM permits flexible assessment of outcome trajectories, including separate estimates of the level of the outcome at the intercept (where time is centered at zero in time-series models) and rates of change in the outcome (i.e., slope). This type of trajectory analysis protects the intra-individual variation that is essential to this study's hypotheses, and that is otherwise lost in more crude measures of physiological change (e.g., area under the curve computations; Hruschka et al., 2005). Moreover, MLM allows for controlled testing of within- and between-subjects effects on each of these trajectory components, as well as cross-level interactions (Curran et al., 2010). 3) MLM is robust to missing data at level-1 (the epoch level in the current study). Rather than simply imputing data for each time point, MLM estimates missing data based on the average trend line for that individual in the context of all other variables in the model (Hedeker & Gibbons, 1997). As such, it represents a more powerful method for managing missing data in time-series datasets.

The final dataset included 83 mother-infant dyads with useable maternal RSA data for all three sections of the SFP (see participant section above for comparison to full sample). Separate two-level multilevel models were constructed for the still face episode and the reunion episode, using the same 83 dyads in each (to permit continuity and comparison between these analyses). In both models, level-1 represented data collected at the epoch level. Maternal RSA values were entered as the outcome variable. Infant distress scores were person-mean centered and entered as a time-varying level-1 predictor. Following Oppenheimer et al.'s (2013) approach, linear time was centered at the mid-point of each episode, at epoch 6 (i.e., epoch 1 = -5, epoch 2 = -4, epoch 3 = -3, epoch 4 = -2, epoch 5 = -1, epoch 6, = 0, epoch 7 = 1, … epoch 12 = 6). Thus, the intercept value represented the level of maternal RSA in the middle of each episode. Quadratic time was also tested in each model (entered as linear time squared). Between-subject factors were grand-mean centered and entered as level-2 predictors. These level-2 variables included the constructs of interest (maternal emotional availability, maternal depressive symptoms, maternal anxiety symptoms) and any covariates that emerged as significantly correlated with the outcome in the preliminary analyses. All models were built in a hypothesis driven, blocked approach using full maximum likelihood estimation (McCoach & Black, 2008; Singer & Willet, 2003). Model building began with an unconditional means model (null model) followed by testing an unconditional linear growth model and an unconditional linear and quadratic growth model. Potential covariates were tested on these unconditional growth models and retained in subsequent models, as necessary. The impact of level-1 predictors was tested before assessing level-2 predictors. Cross-level interactions (i.e., the interaction between maternal factors and infant distress) involved adding level-2 maternal predictors to the infant distress component at level-1. Within-level interactions (e.g., hypotheses assessing the interaction between maternal mood and anxiety symptoms) were computed by adding the product of those factors to the appropriate level (in all cases this was level-2). Main effect and interaction parameters were retained under the following conditions (Raudenbush et al., 2011; Singer & Willet, 2003): i) they were essential to the theoretical structure of the model or hypotheses (e.g., linear time was a critical feature of the model regardless of its significance, a non-significant main effect was retained if it was involved in a significant interaction); ii) their addition improved model fit compared to the relevant comparison model; iii) there was significant random variance in the associated parameters to justify their inclusion (e.g., significant between-subjects variance in RSA slope to justify predicting this variance with between-subject factors); and iv) retention of the parameter did not lead to difficulties with model convergence or parameter reliability. Level-1 residuals and level-2 ordinary least squares residuals were examined for violations of homogeneity assumptions. All models were estimated with MLM software (HLM-8, *Scientific Software International, Inc.*).

Missing data were assessed at each level. In the still face episode, there was maternal RSA data available for 84.24% of the 996 possible epochs (839 epochs available) and infant distress available for 86.65% (863 epochs available). In the reunion episode, of a total of 996 possible epoch data points, there was maternal RSA data available for 78.50% of them (782 epochs available) and infant distress data available for 86.80% of them (865 epochs available).[11]

[11] The difference in missing data between maternal RSA and infant distress is because of a slight timing discrepancy between the computer markers used for physiology collection and the video markers used for infant affect. For example, when the SFP ended, the research assistant pressed the final physiology marker on the computer and then

Missing epochs were the result of early termination due to infant distress. These missing data estimates are comparable to those of Oppenheimer et al. (2013) and are sufficient for MLM requirements. MLM is not robust to missing data at level-2 and will delete subjects listwise if any data is missing at this level. As such, imputation procedures were used to retain all dyads with available maternal RSA. The only missing level-2 data point came from one participant who had missed (or skipped) one item on the PSWQ. The individual's item mean on the PSWQ was substituted for their missing item value to compute their total score.

CHAPTER 3: Results

Descriptive Analyses, Average RSA Pattern and Covariate Identification

Descriptive statistics and correlations for maternal RSA, infant distress, maternal depressive symptoms, maternal anxiety symptoms, and maternal emotional availability are presented in Table 6. RSA values were naturally log transformed, as is typical in the reporting of this biomarker. A repeated measures ANOVA with a Greenhouse-Geisser correction was used to determine the average pattern of RSA response across episodes of the SFP (as is typically reported in the literature). There was a significant episode effect, $F(1.61, 130.13) = 8.19$, $p = .001$, such that maternal RSA changed across time (see Figure 1). Simple contrasts revealed that maternal RSA significantly increased on average in the still face episode compared to the baseline episode ($F(1) = 15.09$, $p < .001$) and recovered to baseline levels in the reunion, on average ($F(1) = 1.03$, $p = .314$).

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walked into the experimental room to end the procedure. The opening of the experimental room door was used as the visual marker in affect coding, whereas the computer marker was used in the physiology extraction.

Table 6

Descriptive Statistics and Correlations for Main Study Variables

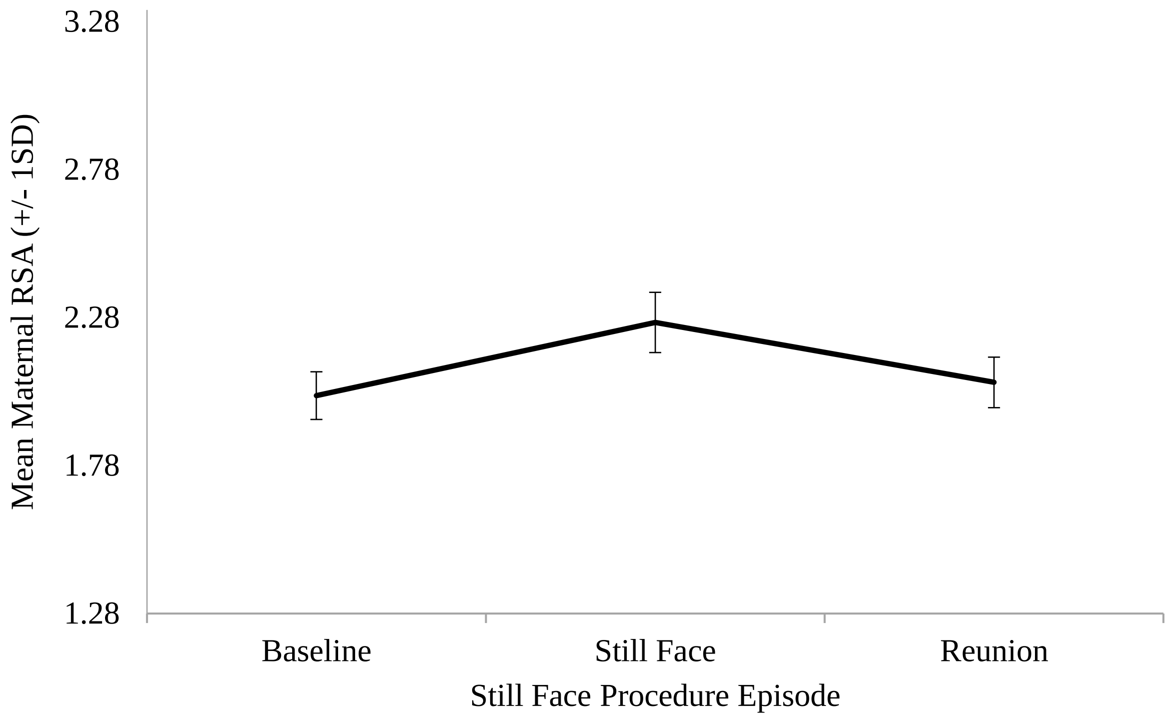
Variable	*M*	*SD*	Possible range	1.	2.	3.	4.	5.	6.	7.
1. Maternal EAS composite score	81.26	18.05	29 – 116	-						
2. Maternal EPDS total score	6.99	4.56	0 – 30	-0.18	-					
3. Maternal PSWQ total score	48.17	12.78	16 – 80	-0.11	.68***	-				
4. Infant distress in SF	2.14	0.83	0 – 4	-0.21ǂ	0.00	0.11	-			
5. Infant distress in reunion	1.97	1.11	0 – 4	-0.14	-0.01	0.07	0.66***	-		
6. Maternal RSA (grand mean) in baseline	2.02	0.73	-	-0.17	0.23*	0.19ǂ	0.02	-0.15	-	
7. Maternal RSA (grand mean) in the SF	2.26	0.93	-	-0.01	0.16	0.17	0.02	-0.15	.77***	-
8. Maternal RSA (grand mean) in reunion	2.06	0.78	-	-0.09	0.20ǂ	0.09	0.10	-0.03	.82***	.66***

Note. EAS = Emotional Availability Scales; EPDS = Edinburgh Postnatal Depression Scale; PSWQ = Penn State Worry Questionnaire; SF = still face episode; RSA = respiratory sinus arrhythmia in $\ln(ms)^2$

* $p \leq .05$, ** $p < .01$, *** $p < .001$, ǂ $p < .10$

Figure 1

Mean Maternal RSA Levels Across Episodes in the Still Face Procedure



Note: Maternal RSA is in $\ln(ms)^2$ units. Errors bars represent ± 1 standard error of the mean maternal RSA for that episode.

Table 7 outlines bivariate correlations between maternal RSA, demographic factors, and other potential covariates, used to determine their inclusion in multilevel models. Of the demographic factors, only maternal age warranted further exploration, as it approached significance in both the still face episode and the reunion episode, with older mothers tending to have lower overall levels of RSA. Baseline grand mean RSA values were significantly positively correlated with RSA in the still face and reunion episodes, consistent with Oppenheimer et al. (2013). That is, individuals with higher RSA in the baseline episode were more likely to have higher overall RSA in each subsequent episode. As such, average baseline RSA was tested as a covariate in both the still face and reunion models.

Other potential covariates did not significantly correlate with maternal RSA, including the percentage of divergent maternal still face frames and the overall percentage of manual heartbeat corrections. Thus, these variables were excluded from the multilevel models. Of the 78 mothers with medication data available, zero reported taking tricyclic antidepressants and three reported SSRI use. The limited number of mothers taking antidepressants precluded statistical comparison of this group to the larger sample. However, visual examination of the episode means indicated that mothers taking SSRIs had maternal RSA values within a ±1 SD range in the baseline episode (SSRI ±1 SD range = 1.83 to 2.41; non-SSRI ±1 SD range = 1.27 to 2.74) and still face episode (SSRI ±1 SD range = 1.37 to 2.53; non-SSRI ±1 SD range = 1.30 to 3.20). Mothers taking SSRIs tended to have more extreme values in the reunion episode (SSRI ±1 SD range = 1.16 to 3.19; non-SSRI ±1 SD range = 1.31 = 2.82), though not in a consistent direction. Taken together, maternal SSRI use is unlikely to significantly impact the maternal RSA results herein.

Table 7

Correlations between Maternal RSA, Demographic Factors and Other Potential Covariates

	Maternal Factor					Infant Factor	
Potential Covariate	RSA in SF	RSA in Reunion	EAS	EPDS	PSWQ	Distress in SF	Distress in Reunion
Maternal age	-.21ǂ	-.19ǂ	.32**	-.17	-.10	-.12	.02
Racial/ethnic identity (dichotomous)	.10	.01	-.03	.07	-.01	.13	.14
Marital status (dichotomous)	-.11	.04	-.18	.07	.04	.02	.22*
Education level (dichotomous)	-.07	.02	-.34	.07	-.19ǂ	-.21ǂ	-.14
Family income level	-.03	.00	.31**	-.17	-.19ǂ	.05	-.08
% of divergent maternal still face frames	-.03	-	.08	-.04	.10	.17	.14
% of RSA manual waveform corrections	.09	.04	-.03	-.05	-.16	.15	.10
Maternal average baseline RSA	.77***	.82***	-.15	.23*	.20ǂ	.02	-.15

Note. Racial and ethnic identity was dichotomized as individuals identifying as White compared to individuals identifying as Black, Indigenous or Person of Colour. Marital status was dichotomized as married or common-law status compared to single, widowed, divorced or not-common-law relationship. Education level was dichotomized as individuals with post-secondary education versus secondary education or less. Only covariates that correlated with maternal RSA in the still face episode or reunion episode were explored in the multilevel models.

RSA = respiratory sinus arrhythmia in $\ln(ms)^2$; SF = still face episode

* $p \leq .05$, ** $p < .01$, *** $p < .001$, ǂ $p < .10$

Factor Analysis of Maternal Emotional Availability Scales

The four maternal emotional availability scales (total scores) correlated with one another at high levels (see Table 8). A principal component analysis was conducted to determine if a composite variable would be more appropriate to use (which would also reduce unnecessary parameters in the multilevel models). Following methods by Wiefel and colleagues (2005), a varimax rotation was used to restrict component dependence within the factor solution. All four subscales loaded highly onto a single factor, which explained 82.71% of the variance (no other factor had an eigenvalue greater than one; Guadagnoli & Velicer, 1988). The component loadings for each item were as follows: .96 for sensitivity, .91 for non-intrusiveness, .90 for structuring, and .85 for non-hostility. As such, the use of a composite variable (created by summing all four total scale scores) was justified. This composite score represents a global estimate of maternal emotional availability (also referred to as sensitivity herein).

Table 8

Correlations between the Adult Emotional Availability Scales Total Scores

Variable	1.	2.	3.	4.
1. Sensitivity total scale score	-			
2. Structuring total scale score	.90*	-		
3. Non-intrusiveness total scale score	.86*	.73*	-	
4. Non-hostility total scale score	.78*	.64*	.70*	-

* $p < .001$

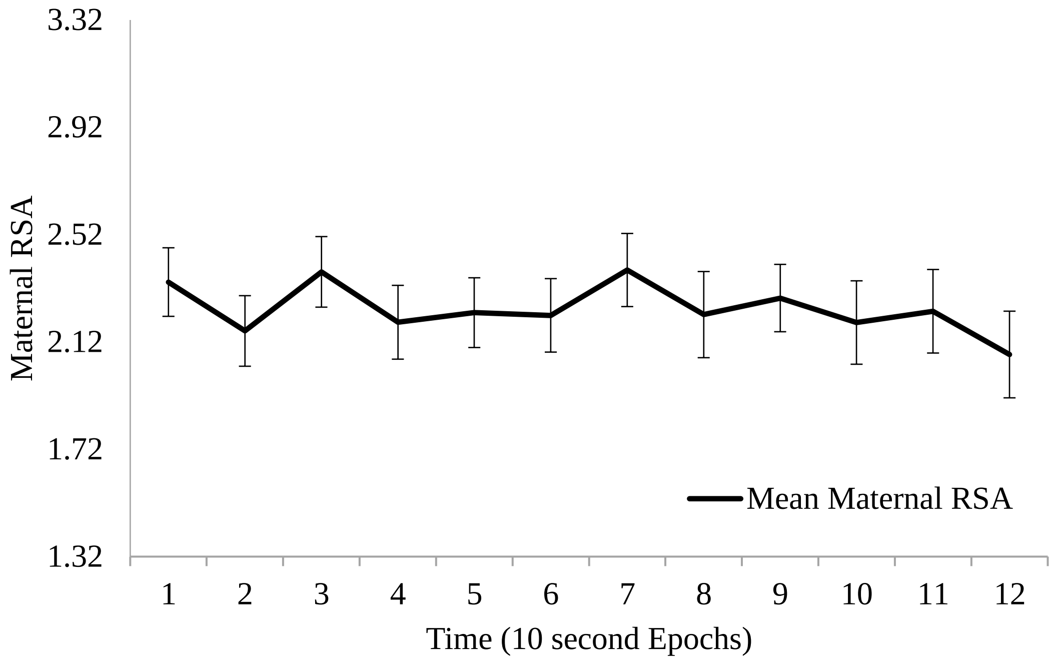
Still Face Episode Results

Visual Inspection of Average Maternal RSA and Infant Distress Trajectories in the Still Face

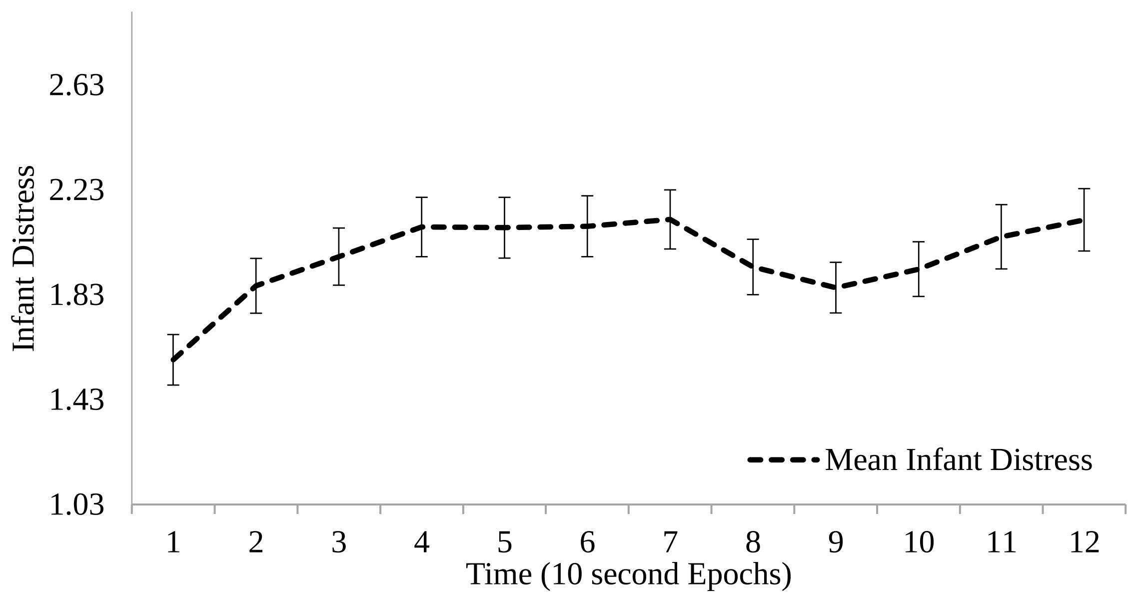
Average levels of maternal RSA and infant distress across time in the still face episode are presented in panels A and B of Figure 2, respectively. The average trend of maternal RSA in this episode is relatively flat (see panel A). However, standard error bars indicate variance between mothers across the trajectory. Infant distress (see panel B) increases over time, with a slight recovery around the last third of the episode. Of note, the averages used in each epoch of Figure 2 are based on the number of participants who had data available for that epoch. That is, infants who found the still face highly distressing may not be represented in the last several epochs due to early episode termination. MLM accounts for these missing data by estimating an individual's trend based on the pattern exhibited from their existing data. Thus, these visual depictions should be interpreted with caution.

Figure 2

Average Trajectories of (A) Maternal RSA and (B) Infant Distress Across Time in the Still Face Episode



A)



B)

Note: Plot (A) depicts maternal RSA across 10 second epochs in the still face episode. Plot (B) depicts infant distress across the still face episode. Errors bars represent ± 1 standard error value for that epoch. Values on the y-axis were selected to encompass the ± 1 standard deviation range for that variable.

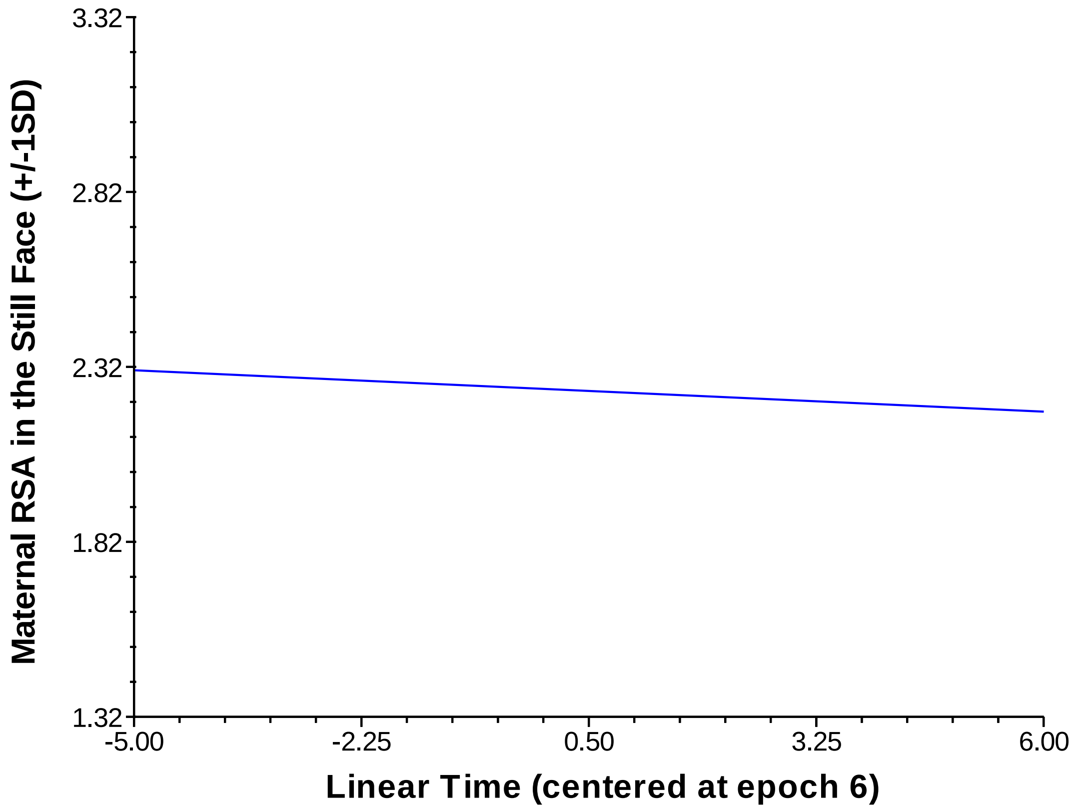
Unconditional Models and Covariate Assessment

Prior to examining specific hypotheses, MLM analyses began by testing the unconditional means (null) model, which included only maternal RSA as the outcome variable and was used to partition the amount of intra-individual and inter-individual variance in physiology. The intraclass coefficient (ICC) value indicated that 54.74% of the variance in maternal RSA existed between individuals (at level 2). Thus, there was justification for exploring between-person predictors of this variance. The ICC also supported the inclusion of within-dyad predictors as 45.26% of the variance existed at level-1. The intercept value of the null model confirmed that the sample grand mean of maternal RSA (across all time points in the still face episode) was 2.26 $\ln(\text{ms})^2$. There was significant random variance in the mean level of RSA between mothers.

To determine the average linear trajectory of maternal RSA across the sample, an unconditional linear growth model was tested next, with linear time (centered at epoch 6) entered as a level-1 predictor. The inclusion of linear time improved model fit ($\chi^2(3) = 12.86$, $p <.001$). The average slope was not significantly different from zero (coefficient = -.01, $p = .314$), indicating a generally flat trajectory in the sample overall (see Figure 3). However, there was significant variance in the slope ($\chi^2(82) = 125.55$, $p = .002$), such that the rate of change in maternal RSA was not consistent across the sample and could be explored with level-2 predictors. The addition of linear time accounted for 5.7% of the within-person variance (pseudo R^2). The covariance correlation coefficient indicated that there was a positive, non-significant correlation between maternal RSA intercept and slopes ($r = .24$).

Figure 3

Fixed Effect Linear Growth Trajectory of Maternal RSA in the Still Face Episode



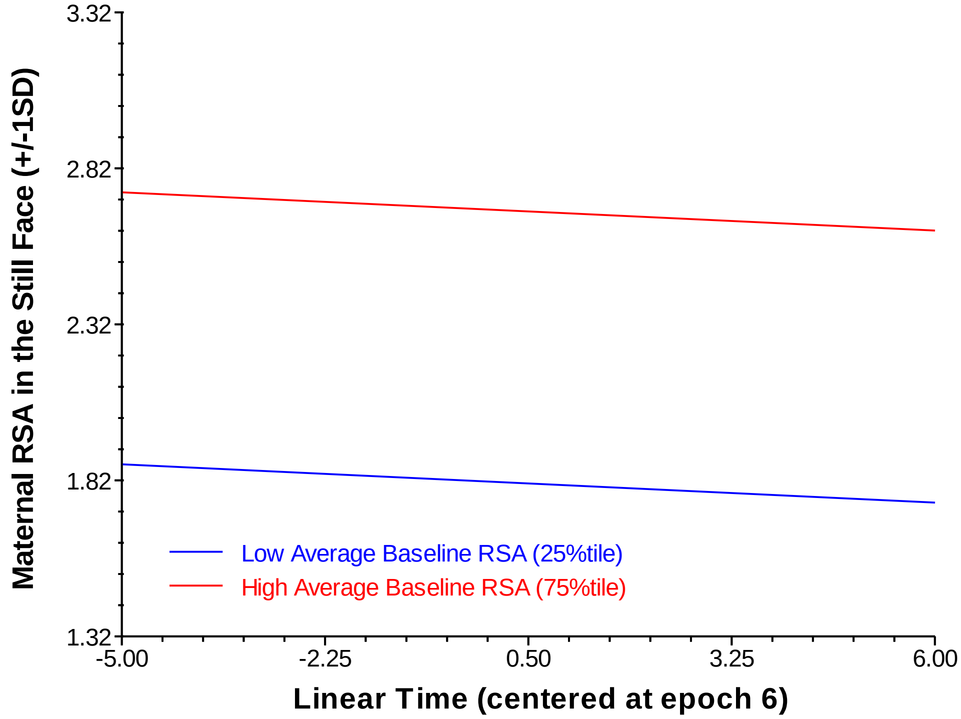
Note. The y-axis represents the +/-1SD range of grand mean maternal RSA $\ln(ms)^2$ values in the still face episode. The x-axis plots the entire range of linear time, centered at epoch 6.

Quadratic time (centered at epoch 6) was entered next to determine if maternal RSA exhibited a non-linear trajectory across the still face, on average. Quadratic time significantly improved model fit ($\chi^2(4) = 10.77$, $p = .029$) compared to the unconditional linear growth model. The main effect of quadratic time was not significant (coefficient = -.003, $p = .302$), such that there was not evidence of an average rate of acceleration (or deceleration). There was, however, significant variation in the random quadratic slope parameter ($\chi^2(81) = 105.75$, $p = .034$). The inclusion of quadratic time accounted for an additional 3.3% of within-person variance. Notably, the reliability estimate for the random component of quadratic time was lower than ideal (.155; Raudenbush et al., 2011 suggest very low reliability around .10 should be assessed as fixed effects). As such, the decision to retain quadratic time in subsequent models was tentative.

The influence of covariates was tested on and compared to the unconditional linear and quadratic growth model. Maternal average baseline RSA and maternal age (both grand mean centered) were tested as level-2 predictors of the intercept, linear slope and quadratic slope in separate models and together. A model with maternal average baseline RSA significantly improved fit ($\chi^2(3) = 77.46$, $p < .001$). There was a significant main effect of maternal average baseline RSA on the intercept of maternal RSA in the still face (coefficient = 1.06, $p < .001$); for each one-unit increase of average baseline RSA, mothers had a 1.06 difference in their intercept value (at epoch 6). That is, mothers with higher average baseline RSA tended to have higher RSA at epoch 6, and mothers with lower average baseline RSA tended to have lower RSA at epoch 6 (see Figure 4). The inclusion of this covariate accounted for 69.07% of the between-subjects variance (pseudo R^2) in the intercept, although significant variance remained. Maternal average baseline RSA was not significantly related to average linear slope and significant variation in this random parameter remained. The effect of average maternal baseline RSA on quadratic slope approached significance (coefficient = -.007, p = .089). Notably, the inclusion of this covariate reduced the random variance in the quadratic slope parameter to a non-significant level. As such, there is little justification for further estimating the quadratic trajectory parameter with between-subject predictors. This finding, combined with the low reliability estimate for the quadratic random parameter, led to quadradic time being removed from subsequent models to achieve parsimony. This model supported the inclusion of maternal average baseline RSA as a covariate of the intercept maternal RSA.

Figure 4

Graphical Depiction of the Fixed Effect of Maternal Average Baseline RSA on Maternal RSA Trajectories in the Still Face Episode



Note. The y-axis represents the +/-1SD range of grand mean maternal RSA values in the still face episode. The x-axis plots the entire range of linear time, centered at epoch 6. Average baseline RSA $\ln(ms)^2$ values are graphed at the 25th percentile (low) and 75th percentile (high).

A model with maternal age only did not significantly improve model fit ($\chi^2(3) = 3.56$, p = .312). Maternal age had a non-significant trend on the intercept (coefficient = -.04, p = .095), such that a one-year increase in age was associated with a .04 decrease in the level of maternal RSA at epoch 6. Maternal age was not related to RSA linear or quadratic slope. Maternal age and maternal average baseline RSA were also entered in a model together. Maternal age was not a significant predictor of the intercept or slopes. Maternal average baseline RSA remained a significant predictor of the intercept but continued to be unrelated to linear and quadratic growth. Thus, subsequent models were compared to a base model that included linear time (but not quadratic time) and maternal average baseline RSA at the level of the intercept (but not linear slope) (see Equation 1).

Level-1 Model (1)

$$Maternal\ RSA\ in\ SF_{ti} = \pi_{0i} + \pi_{1i}*(Linear\ Time_{ti}) + e_{ti}$$

Level-2 Model

$$\pi_{0i} = \beta_{00} + \beta_{01}*(Average\ Baseline\ RSA_i) + r_0$$

$$\pi_{1i} = \beta_{10} + r_{1i}$$

Hypothesis 1: Maternal RSA Trajectories as Predicted by Infant Distress and Maternal Depressive Symptoms

Prior to incorporating level-2 maternal factors (i.e., maternal depressive symptoms in the context of hypothesis 1), infant distress (person mean centered) was entered as a level-1 predictor to the base model and improved model fit ($\chi^2(4) = 12.86$, p = .012; see Equation 2). Infant distress was not significantly related to maternal RSA on average (coefficient = 0.06, p = .394). However, there was significant variability in this parameter ($\chi^2(81) = 105.75$, p = .034), indicating that maternal physiological activation in the context of infant distress may differ according to between-subject maternal factors. The inclusion of infant distress also reduced the random variance of the linear growth term to a non-significant level. Infant distress accounted for 5.4% of the variance (pseudo R^2) at level-1.

Level-1 Model (2)

$$Maternal\ RSA\ in\ SF_{ti} = \pi_{0i} + \pi_{1i}*(Linear\ Time_{ti}) + \pi_{2i}*(Infant\ Distress_{ti}) + e_{ti}$$

Level-2 Model

$$\pi_{0i} = \beta_{00} + \beta_{01}*(Average\ Baseline\ RSA_{i}) + r_{0}$$
$$\pi_{1i} = \beta_{10} + r_{1i}$$
$$\pi_{2i} = \beta_{20} + r_{2i}$$

To replicate Oppenheimer et al.'s (2013) findings and test hypothesis #1, maternal depressive symptoms (grand mean centered) was entered as a level-2 predictor of the intercept, linear slope and infant distress (see Equation 3). The inclusion of depression significantly improved model fit ($\chi^2(3) = 8.55$, $p = .035$). Maternal depressive symptoms did not have a significant main effect on the intercept (centered at epoch 6; coefficient = -.006, $p = .691$) or linear growth (coefficient = 0.004, $p = .100$). As such, removal of these terms from future models was justified. Consistent with the findings of Oppenheimer et al., maternal depressive symptoms significantly interacted with infant distress to predict maternal RSA (coefficient = .04, $p = .006$) and accounted for 16.78% of the variance (pseudo R^2) in this parameter. As plotted in Figure 5, mothers with fewer depressive symptoms showed evidence of RSA dampening in the context of infant distress. In comparison, mothers with higher levels of depressive symptoms showed increasing RSA in the context of higher levels of infant distress[12].

[12] An online computation tool was used to further probe this interaction (i.e., quantpsy.org; Preacher et al., 2006). Regions of significance tests showed that the simple slope of infant distress on maternal RSA was significantly different from zero at values of maternal depression (grand mean centered) outside of the range of -4.91 to -0.77. In the context of this sample, that range relates to mothers with depressive symptoms slightly below -1 SD and just above mean levels.

Level-1 Model (3)

$$Maternal\ RSA\ in\ SF_{ti} = \pi_{0i} + \pi_{1i}{*}(Linear\ Time_{ti}) + \pi_{2i}{*}(Infant\ Distress_{ti}) + e_{ti}$$

Level-2 Model

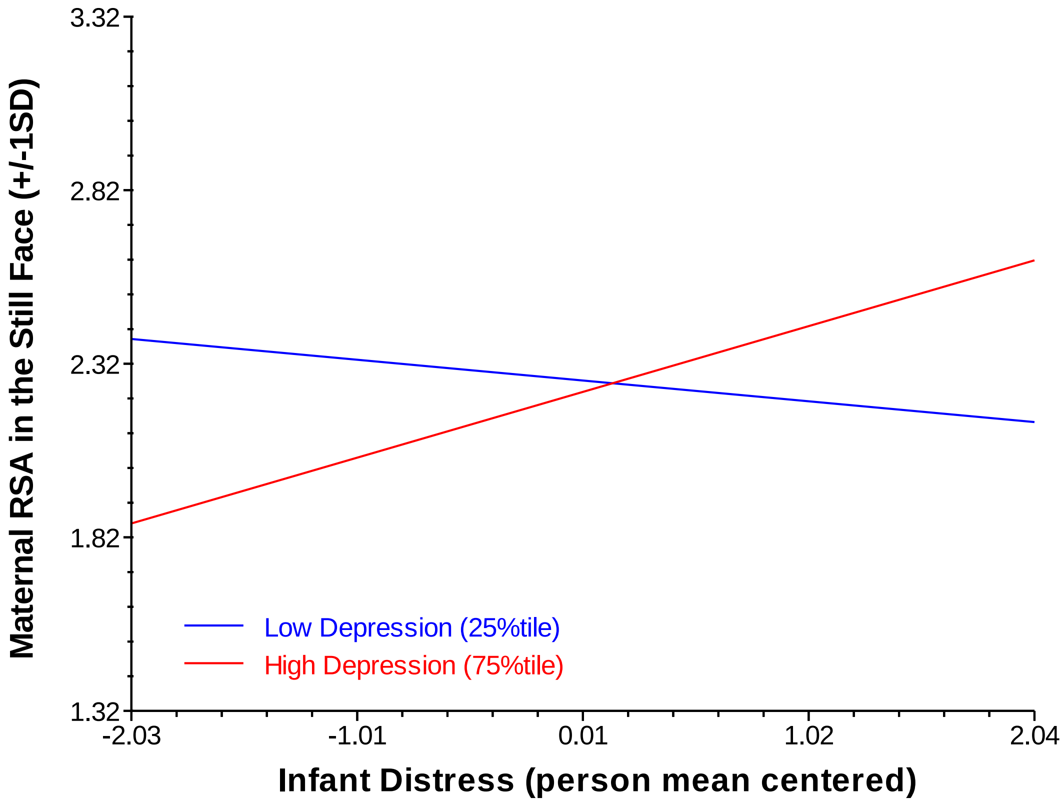
$$\pi_{0i} = \beta_{00} + \beta_{01}{*}(Depression_{i}) + \beta_{02}(Average\ Baseline\ RSA_{i}) + r_{0}$$

$$\pi_{1i} = \beta_{10} + \beta_{11}{*}(Depression_{i}) + r_{1i}$$

$$\pi_{2i} = \beta_{20} + \beta_{21}{*}(Depression_{i}) + r_{2i}$$

Figure 5

Graphical Depiction of the Interaction between Maternal Depressive Symptoms and Infant Distress on Maternal RSA Trajectories in the Still Face Episode



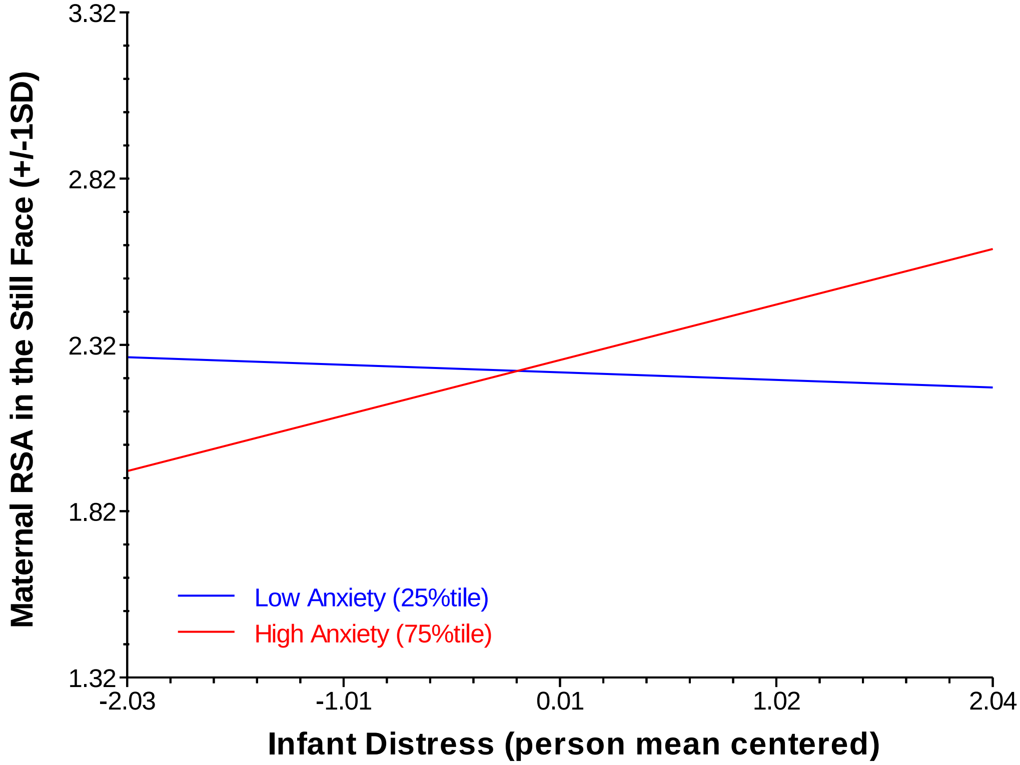
Note. The y-axis represents the +/-1SD range of grand mean maternal RSA $\ln(ms)^2$ values in the still face episode. The x-axis plots the entire range of infant distress (person mean centered). Maternal depressive symptoms correspond to low (25th percentile) and high (75th percentile) total scores on the Edinburgh Postnatal Depressive Scale (grand mean centered).

Maternal RSA Trajectories as Predicted by Infant Distress and Maternal Anxiety Symptoms

The next model assessed the potential isolated role of maternal anxiety on maternal RSA trajectories. As discussed within the introduction, the main effect of maternal anxiety on maternal RSA was not expected to be significant. The inclusion of maternal anxiety did not improve fit ($\chi^2(3) = 5.51$ $p = .136$), indicating that the model's main and random effects should be interpreted with caution. Maternal anxiety symptoms did not have a significant main effect on the intercept but did have a significant main effect on linear slope, such that mothers with higher levels of anxiety had a greater rate of change (coefficient = -0.001, $p = .047$). There was no significant random variance in the linear term to predict. Maternal anxiety symptoms did not significantly impact the relation between infant distress and maternal RSA (coefficient = .009, $p = .106$). However, high anxiety symptoms showed the same trend as depressive symptoms (see graphical depiction in Figure 6). This result was consistent with Oppenheimer et al. (2013). Yet, given the lack of significant model improvement and the knowledge from the previous model emphasizing the role of maternal depression, findings pertaining to maternal anxiety should likely only be considered in a model accounting for maternal depression.

Figure 6

Graphical Depiction of the Interaction between Maternal Anxiety Symptoms and Infant Distress on Maternal RSA Trajectories in the Still Face Episode



Note. The y-axis represents the +/-1SD range of grand mean maternal RSA $\ln(ms)^2$ values in the still face episode. The x-axis plots the entire range of infant distress (person mean centered). Maternal anxiety symptoms correspond to low (25th percentile) and high (75th percentile) total scores on the Penn State Worry Questionnaire (grand mean centered).

Hypothesis #2: Maternal RSA Trajectories as Predicted by Infant Distress, Maternal Depressive Symptoms and Maternal Anxiety Symptoms

To test the interactive effects of maternal mood and anxiety (as per hypothesis #2), maternal anxiety symptoms (grand mean centered) were added as individual predictors and in interaction with maternal depression to equation 3. This model did not improve fit compared to the model with depressive symptoms only ($\chi^2(6) = 9.11$, $p = .167$). Maternal anxiety did not have a significant main effect on the intercept (coefficient = 0.005, $p = .418$), linear growth (coefficient = -.002, $p = 0.121$) or on the relationship between infant distress and maternal RSA (coefficient = -0.003, $p = .631$). Furthermore, maternal anxiety symptoms and depressive symptoms did not significantly interact to predict the intercept (coefficient = -0.0008, $p = .412$) or linear growth (coefficient = -.00008, $p = .618$). However, the interaction between maternal anxiety symptoms and maternal depressive symptoms on the relationship between infant distress and maternal RSA approached significance (coefficient = -0.002, $p = .058$). In this model, maternal depressive symptoms continued to significantly predict the relationship between infant distress and maternal RSA (coefficient = 0.06, $p = .004$).

To achieve a more parsimonious model, the influence of maternal depressive symptoms and maternal anxiety symptoms were dropped as predictors of the intercept and linear growth and retained as predictors of infant distress on maternal RSA (see Equation 4; see Table 9). This model improved fit compared to the model with maternal depression alone ($\chi^2(3) = 11.56$, $p = .009$). A significant main effect of infant distress emerged in this model, with a one-point increase in infant distress associated with a 0.16 $\ln(\text{ms})^2$ increase in maternal RSA ($p = .042$); however, there was significant variability in this relationship ($p = .002$). Maternal depressive symptoms continued to significantly predict the interaction between infant distress and maternal

RSA (coefficient = .05, p = .007). Anxiety was not a significant predictor of this relationship (p = .527). However, the interaction between depression and anxiety on infant distress was significant (coefficient = -.002, p = .018). A visual depiction of this interaction (see Figure 7) suggests that anxiety symptoms may mitigate the relationship between depressive symptoms and infant distress. That is, mothers with high depression and low anxiety showed less RSA withdrawal compared to mothers with high depression and high anxiety. Yet, in both cases, mothers with high depressive symptoms are failing to mount a physiological response to their infant's distress. Further, mothers with high anxiety and low depression had the greatest RSA decrease in the context of infant distress, suggesting that anxiety without depression may account for a distinct profile (potentially one of hyperarousal, as compared to the trajectory of mothers with low anxiety and low depressive symptoms). Collectively, maternal depression, maternal anxiety and their interaction accounted for 26.06% of the variance (pseudo R^2) in the relationship between infant distress and maternal RSA, although significant variance in this parameter remained, justifying further exploration of factors influencing this parameter.

Level-1 Model (4)

$$Maternal\ RSA\ in\ SF_{ti} = \pi_{0i} + \pi_{1i}*(Linear\ Time_{ti}) + \pi_{2i}*(Infant\ Distress_{ti}) + e_{ti}$$

Level-2 Model

$$\pi_{0i} = \beta_{00} + \beta_{01}*(Average\ Baseline\ RSA_i) + r_0$$
$$\pi_{1i} = \beta_{10} + r_{1i}$$
$$\pi_{2i} = \beta_{20} + \beta_{21}*(Depression_i) + \beta_{22}*(Anxiety_i) + \beta_{23}*(Depression*Anxiety_i) + r_{2i}$$

Table 9

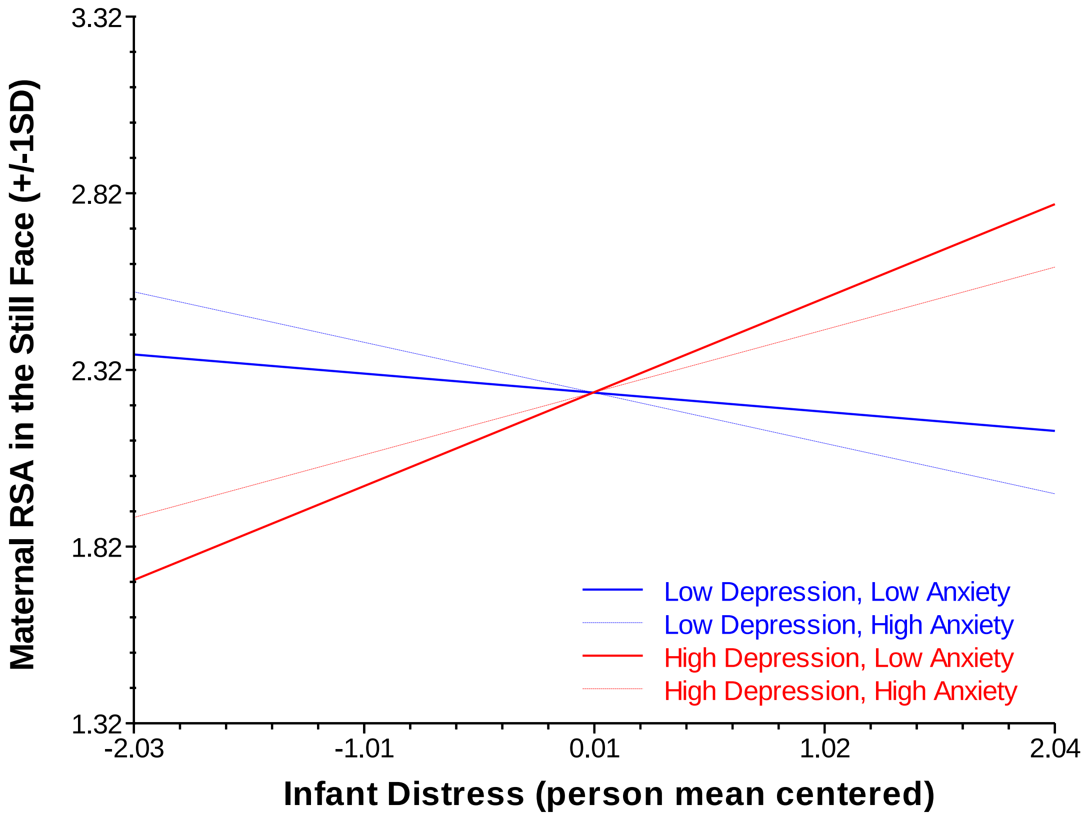
Final Estimation of the Fixed and Random Effects of the Parsimonious Model Examining Maternal Depressive Symptoms, Maternal Anxiety Symptoms and their Interaction on the Relationship Between Infant Distress and Maternal RSA in the Still Face Episode

Predictor – Fixed Effect	Coefficient	SE	*t(df)*	*p*-value
Intercept, β_{00}	2.256	0.06	35.72 (81)	<0.001
Maternal Average Baseline RSA, β_{01}	0.987	0.09	11.59 (81)	<0.001
Linear Slope, β_{10}	-0.011	0.01	-1.08 (82)	0.285
Infant Distress, β_{20}	0.157	0.08	2.07 (79)	0.042
Depressive Symptoms, β_{21}	0.052	0.02	2.78 (79)	0.007
Anxiety Symptoms, β_{22}	-0.004	0.01	-0.64 (79)	0.527
Depression*Anxiety, β_{23}	-0.002	0.00	-2.43 (79)	0.018
Predictor – Random Effect	Standard Deviation	Variance Component	χ^2 (*df*)	*p*-value
Intercept, r_0	0.515	0.265	404.79 (80)	<0.001
Linear Time, r_1	0.038	0.001	96.62 (81)	0.114
Infant Distress, r_2	0.316	0.100	119.71 (78)	0.002
level-1, *e*	0.747	0.558		

Note. RSA = respiratory sinus arrhythmia in $\ln(ms)^2$. Infant distress scores are person mean centered. Depressive symptoms correspond to maternal scores on the Edinburgh Postnatal Depression Scale (grand mean centered). Maternal anxiety symptoms correspond to scores on the Penn State Worry Questionnaire (grand mean centered).

Figure 7

Graphical Depiction of the Interaction between Maternal Depressive Symptoms, Maternal Anxiety Symptoms, and Infant Distress on Maternal RSA Trajectories in the Still Face Episode



Note. The y-axis represents the +/-1SD range of grand mean maternal RSA $\ln(\text{ms})^2$ values in the still face episode. The x-axis plots the entire range of infant distress (person mean centered). Maternal depressive symptoms correspond to low (25^{th} percentile) and high (75^{th} percentile) total scores on the Edinburgh Postnatal Depressive Scale (grand mean centered). Maternal anxiety symptoms correspond to low (25^{th} percentile) and high (75^{th} percentile) total scores on the Penn State Worry Questionnaire (grand mean centered).

Hypothesis #3: Maternal RSA Trajectories and Associations with Maternal Emotional Availability and Infant Distress

The isolated effect of maternal emotional availability (EAS composite grand mean centered) on maternal RSA trajectories and the relationship between infant distress and maternal RSA was tested in a model without depression or anxiety (as per hypothesis #3). This model did not significantly improve model fit ($\chi^2(3) = 3.94$, $p = .267$), indicating that effects should be interpreted with caution. The main effect of maternal emotional availability on the level of maternal RSA at the intercept (epoch 6) showed a trend towards significance (coefficient = .006, $p = .092$), such that a one unit increase in emotional availability was associated with a .006 unit increase in RSA. Maternal emotional availability did not significantly relate to linear growth (coefficient = -.0005, $p = .355$) or the influence of infant distress on maternal RSA (coefficient = -.002, $p = .677$). Overall, there was little evidence to suggest that maternal emotional availability (in isolation) related to maternal RSA trajectories.

Hypothesis #4: Maternal RSA Trajectories and Associations with Maternal Emotional Availability, Maternal Depressive and Anxiety Symptoms, and Infant Distress

To test hypothesis #4, maternal caregiving behaviour was added to the parsimonious model of maternal depressive symptoms, maternal anxiety symptoms and their interaction with infant distress (i.e., added to equation 4). In this model, maternal emotional availability (grand mean centered) was included as a predictor of the intercept, linear slope, and infant distress and in interaction with depression, anxiety, and depression x anxiety on infant distress (see Equation 5)[13]. This model did not improve fit compared to the model without maternal caregiving behaviour ($\chi^2(6) = 4.90$, $p > .500$). Maternal caregiving behaviour continued to show a trend towards a main effect on the intercept (coefficient = 0.006, $p = .089$), but this effect was neither significant, nor did its inclusion improve model fit. Maternal caregiving behaviour did not significantly impact the linear growth of maternal RSA (coefficient = -.0005, $p = .383$) or the relationship between infant distress and maternal RSA (coefficient = .001, $p = .760$). Further, maternal caregiving behaviour did not significantly interact with maternal depressive symptoms, maternal anxiety symptoms or depression x anxiety on the relationship between infant distress and maternal RSA. In this model, maternal depressive symptoms and maternal depressive symptoms x maternal anxiety symptoms continued to have significant effects on the relationship between infant distress and maternal RSA (coefficient = 0.05, $p = .008$, and coefficient = -0.002, $p = .018$, respectively). Overall, this model did not support maternal caregiving behaviour as a significant predictor of maternal RSA trajectories in the still face episode, in isolation or in interaction with infant distress, maternal depression and maternal anxiety. These results do not

[13] A full model with all main effects and interaction effects between maternal caregiving behaviour, maternal depressive symptoms, maternal anxiety symptoms and infant distress on maternal RSA slope *and* intercept was tested. There was no significant improvement in model fit, which is not surprising considering the number of parameters involved in this model. There were no significant effects of maternal caregiving behaviour in this model.

support the hypothesis that mothers with more optimal parenting behaviour differ from mothers with less optimal parenting behaviour on their likelihood of withdrawing RSA in the still face episode. Instead, maternal depression and maternal depression x maternal anxiety appear to be the strongest predictors of maternal parasympathetic regulation in the still face episode.

Level-1 Model (5)

$$\textit{Maternal RSA in SF}_{ti} = \pi_{0i} + \pi_{1i}*(\textit{Linear Time}_{ti}) + \pi_{2i}*(\textit{Infant Distress}_{ti}) + e_{ti}$$

Level-2 Model

$$\pi_{0i} = \beta_{00} + \beta_{01}*(\textit{Caregiving}_i) + \beta_{02}(\textit{Average Baseline RSA}_i) + r_0$$

$$\pi_{1i} = \beta_{10} + \beta_{11}*(\textit{Caregiving}_i) + r_{1i}$$

$$\pi_{2i} = \beta_{20} + \beta_{21}*(\textit{Caregiving}_i) + \beta_{22}*(\textit{Depression}_i) + \beta_{23}*(\textit{Anxiety}_i) + \beta_{24}*(\textit{Caregiving*Depression}_i) + \beta_{25}*(\textit{Depression*Anxiety}_i) + \beta_{26}*(\textit{Caregiving*Anxiety}_i) + \beta_{27}*(\textit{Caregiving*Depression*Anxiety}_i) + r_{2i}$$

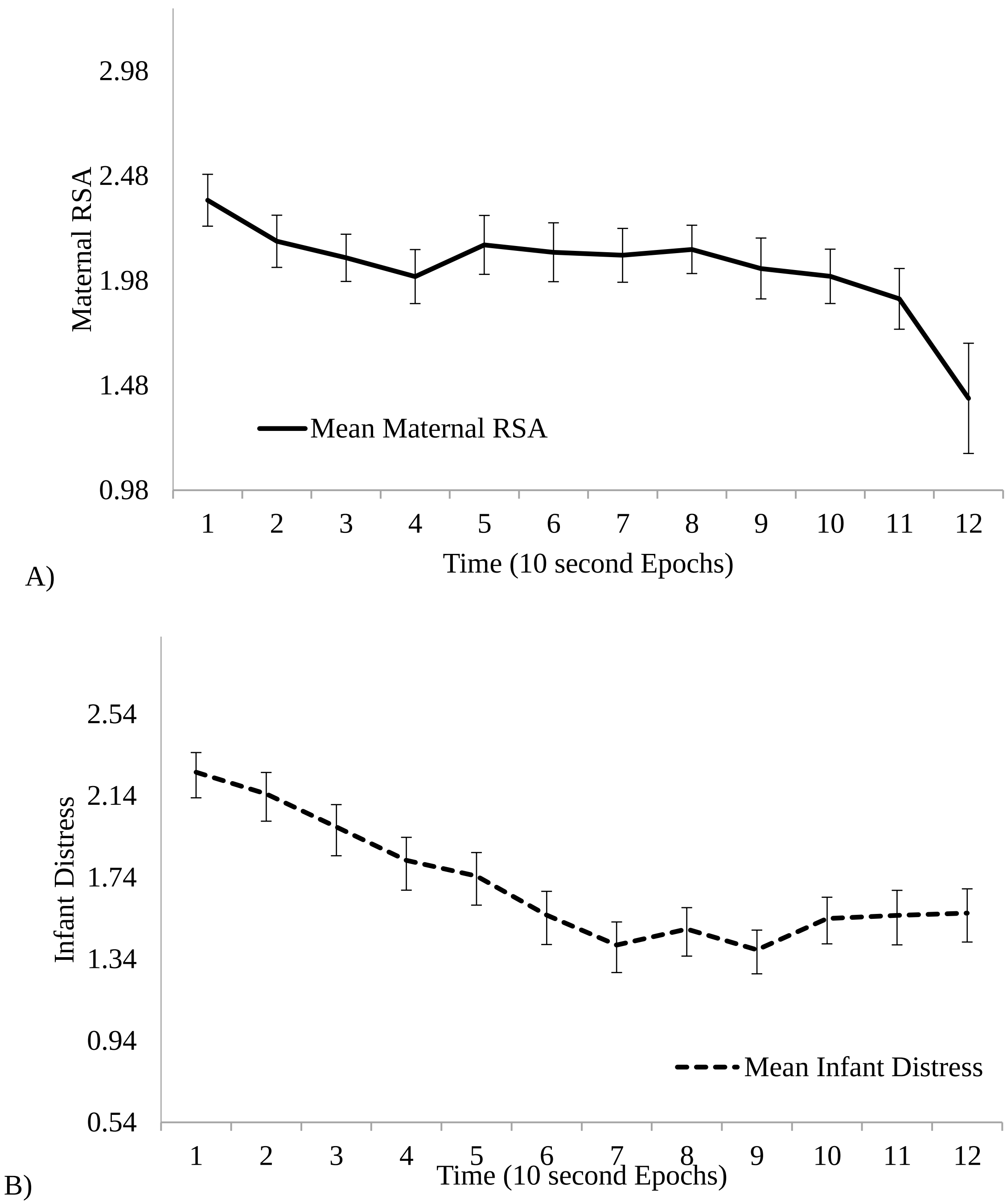
Reunion Episode Results

Visual Inspection of Average Maternal RSA and Infant Distress Trajectories in the Reunion

Average maternal RSA and infant distress trajectories in the reunion episode are plotted in panels A and B of Figure 8. Maternal RSA (see panel A) consistently declined in the first four epochs of the episode with some evidence of a plateau between 5 and 9, followed by a downward trend. However, the error bars of this average trajectory indicate variation in the sample. Infant distress (see panel B) declined over time, with some evidence of a plateau or slight increase in the last few epochs. The error bars indicate some variation in infant distress. The epoch means in this figure are based on participants with data available for that epoch. Thus, infants with data available in the later epochs were able to surmount the SFP and tended to show mild-to-neutral distress within these epochs, on average. The plotted data help characterize the overall trends in responses but portrays a bias that is corrected in the multilevel models (as discussed above with relation to the still face episode).

Figure 8

Average Trajectories of (A) Maternal RSA and (B) Infant Distress Across Time in the Reunion Episode



Note: Plot (A) depicts maternal RSA $\ln(ms)^2$ across 10 second epochs in the reunion episode. Plot (B) depicts infant distress across the still face episode. Errors bars represent ± 1 standard error value for that epoch. Values on the y-axis were selected to encompass the ± 1 standard deviation range across all epochs for that variable.

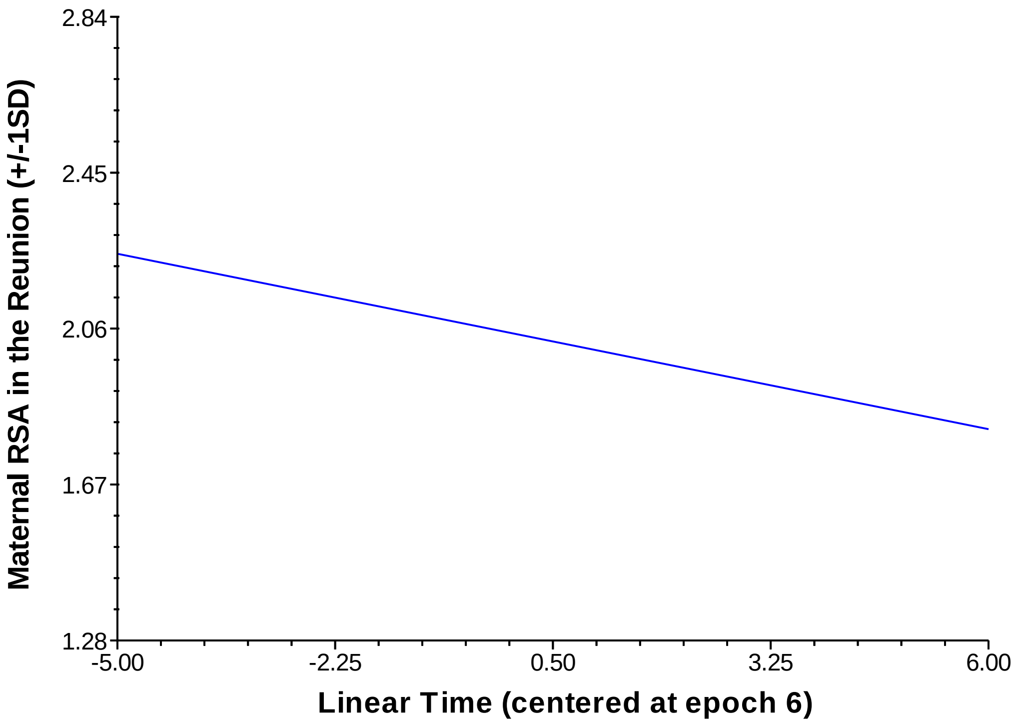
Unconditional Models and Covariate Assessment

An unconditional means (null) model was computed to quantify intra-individual and inter-individual levels of variation in maternal RSA trajectories in the reunion episode. The ICC indicated that 41.63% of the variance in maternal RSA in the reunion existed between individuals (at level 2). Thus, there was justification for exploring between-subject predictors of this variance. The ICC also justified the inclusion of within-subject predictors, as 58.37% of the variance existed at the epoch level (level 1). The model intercept coefficient indicated that the overall grand mean of maternal RSA in the reunion was 2.06 $\ln(\text{ms})^2$. The random variance component for the intercept was significant, signaling that there was variation in the mean level of RSA between mothers.

Linear growth was tested in the next model. Linear time (centered at epoch 6) was added as a level-1 predictor to the null model. The inclusion of linear time improved model fit ($\chi^2(3) = 30.05$, $p < .001$). There was a significant main effect of linear time (coefficient = -0.04, $p < .001$), indicating that the average rate of change was significantly different from zero. Specifically, a one-unit increase in time (i.e., one epoch) was associated with a .04 $\ln(\text{ms})^2$ decrease in RSA. Figure 9 depicts the average RSA trajectory in the reunion. The random component of linear growth was also significant ($\chi^2(82) = 333.72$, $p < .001$), indicating that the rate of change was not consistent across mothers. The inclusion of linear time accounted for 8.7% (pseudo R^2) of the within-person variation in maternal RSA in the reunion. The covariance coefficient correlation ($r = -.13$), representing the relationship between an individual's intercept and slope, was negative and nonsignificant.

Figure 9

Fixed Effect Linear Growth Trajectory of Maternal RSA in the Reunion Episode



Note. The y-axis represents the +/-1SD range of grand mean maternal RSA $\ln(ms)^2$ values in the reunion episode. The x-axis plots the entire range of linear time, centered at epoch 6.

An unconditional linear and quadratic growth model was assessed next. The inclusion of quadradic time (centered at epoch 6) did not improve model fit ($\chi^2(4) = 4.50$, $p > .500$) compared to the unconditional linear growth model. In this model, the main effect of linear slope remained significant (coefficient = -0.04, $p < .001$), as did the random variance in this parameter. The intercept also continued to have significant fixed and random effects. The fixed effect of quadratic time was not significantly different from zero (coefficient = -0.002, $p = .525$), such that there was not evidence of an average rate of acceleration (or deceleration). The random quadratic component was also not significant ($p < .500$), negating justification for predicting quadratic growth with level-2 predictors. Further, the reliability estimate for the random quadratic component was small ($r = .09$) and its inclusion accounted for only 1.1% additional variance (pseudo R^2) at level 1. In all, quadratic time was not found to contribute to the model in any meaningful way and its fixed and random effects were removed from subsequent models.

The impact of covariates on maternal RSA trajectories in the reunion episode were assessed next. As in the still face episode analyses, maternal age and maternal average baseline RSA were tested in isolation and together. A model with maternal average baseline RSA[14] (grand mean centered) entered at level 2 significantly improved model fit compared to the unconditional linear growth model ($\chi^2(2) = 103.19$, $p < .001$). There was a significant fixed effect of baseline RSA on the intercept (coefficient = 0.90, $p < .001$); for each one-unit difference in average baseline RSA, mothers had a 0.90 difference in their RSA level at epoch 6. As seen in Figure 10, higher baseline RSA was associated with higher RSA levels at epoch 6 in the reunion,

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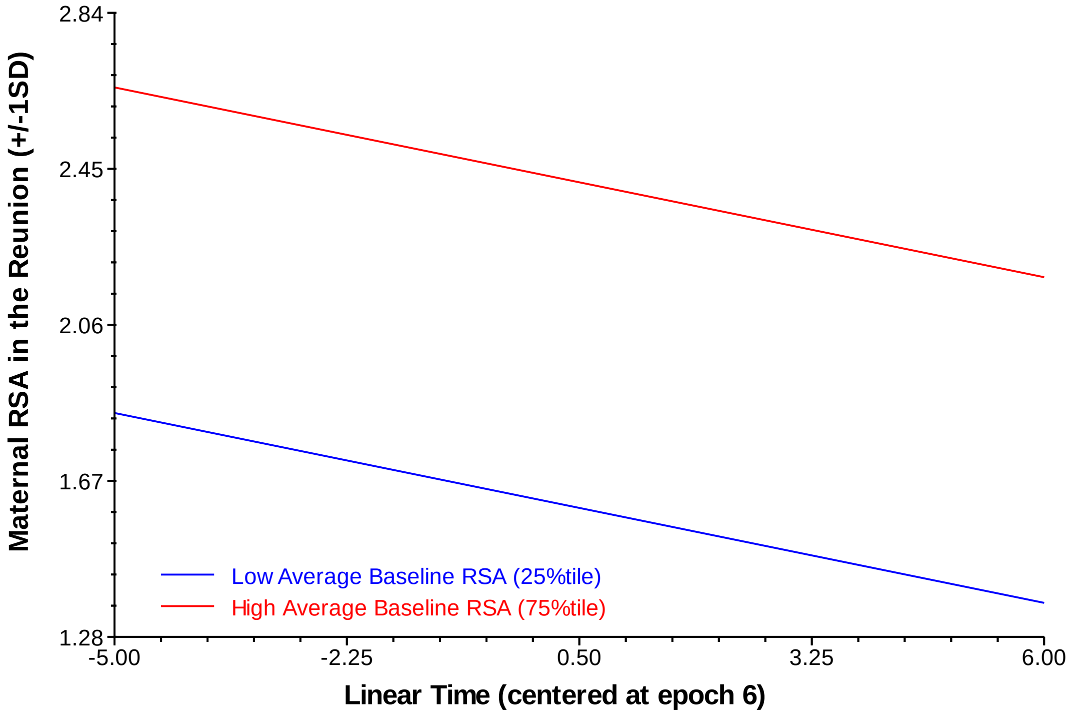
[14] One may reasonably question whether average maternal RSA in the still face episode should be tested as a covariate instead of baseline RSA. This is a valid question but adding average baseline RSA alone achieves what this covariate is set out to do, which is to account for naturally higher resting vagal tone. Adjusting for reactivity in the still face episode is less relevant to this purpose and interferes with model parsimony and continuity between the episode analyses.

and lower baseline RSA was associated with lower RSA levels at epoch 6. Average baseline RSA accounted for 81.96% of the variance (pseudo R^2) in the intercept, although the random intercept component remained significant ($p < .001$). Average baseline RSA was not significantly related to the average linear growth of maternal RSA (coefficient = 0.006, $p = .690$) and the random variance in this parameter remained significant ($p < .001$). This model supported the inclusion of maternal average baseline RSA as a covariate of the intercept in subsequent models.

Figure 10

Graphical Depiction of the Fixed Effect of Maternal Average Baseline RSA on Maternal RSA Trajectories in the Reunion Episode



Note. The y-axis represents the +/-1SD range of grand mean maternal RSA values in the reunion episode. The x-axis plots the entire range of linear time, centered at epoch 6. Average baseline RSA $\ln(ms)^2$ values are graphed at the 25^{th} percentile (low) and 75^{th} percentile (high).

Maternal age (grand mean centered) was added to level-2 of the unconditional linear growth model. The inclusion of this covariate (in isolation) did not significantly improve model fit ($\chi^2(2) = 2.68$, $p = .261$). The main effect of maternal age on the intercept of maternal RSA was not significant (coefficient = -0.04, $p = .105$). Maternal age did not significantly influence the linear rate of change of maternal RSA on average (coefficient = .0005, $p = .855$). Maternal age had minimal impact on the random components of the intercept (3.45% pseudo R^2) and slope (1.14% pseudo R^2), which remained significant. Maternal age was also tested in a model with maternal average baseline RSA. While baseline RSA continued to significantly influence the intercept, the non-significant relations of maternal age endured. Overall, there was no evidence to support the inclusion of maternal age as a covariate of maternal RSA trajectories in the reunion. Therefore, the reunion episode's base model included linear slope (not quadratic slope) and maternal average baseline RSA as a predictor of the intercept (not slope; see Equation 6).

Level-1 Model (6)

$$Maternal\ RSA\ in\ Reunion_{ti} = \pi_{0i} + \pi_{1i}*(Linear\ Time_{ti}) + e_{ti}$$

Level-2 Model

$$\pi_{0i} = \beta_{00} + \beta_{01}*(Average\ Baseline\ RSA_i) + r_0$$
$$\pi_{1i} = \beta_{10} + r_{1i}$$

Maternal RSA Trajectories and their Relation to Infant Distress in the Reunion

The next model examined the relationship between infant distress and maternal RSA in the reunion episode. The inclusion of infant distress (person mean centered) as a level-1 predictor did not improve model fit compared to the base model ($\chi^2(4) = 7.27$, $p = .121$). The main effect of infant distress trended towards significance (coefficient = .09, $p = .097$), though did not improve model fit. Infant distress accounted for an additional 2.74% of the variance (pseudo R^2) at level 1. Contrary to the still face episode, there was not a significant random effect of infant distress on maternal RSA ($\chi^2(75) = 82.50$, $p = .259$). That is, the relationship between maternal RSA and infant distress did not differ significantly between mothers. Assessing the relationship between infant distress and level 2 maternal predictors relies on significant random variance in this parameter. As such, the data do not support the replication of the infant distress by maternal factor models examined in the still face episode.

Unlike the well-established impact of the still face episode on increasing infant negative affect (i.e., 'the still face effect'), the literature finds greater variability in infant affect recovery in the reunion episode (Mesman et al., 2009). As such, it was possible that infant distress interacted with linear time in this episode, such that differences may have occurred at specific epochs rather than general time trends. To determine whether this occurred, a model with an interaction between infant distress and linear time was tested (see Equation 7). This model did not significantly improve fit ($\chi^2(5) = 5.86$, $p = .319$). The fixed effect of the distress x time interaction was not significant (coefficient = 0.004, $p = .807$). There was significant random variance in this interaction ($\chi^2(69) = 91.52$, $p = .036$), but this should be interpreted with caution because of the overall model fit comparison and because the reliability of this estimate was low ($r = .07$). In this model, infant distress continued to show a statistical trend in its main effect (coefficient = .09, $p = .085$) and there was a trend towards significance in the random parameter ($\chi^2(69) = 88.18$, $p = .060$). Collectively, there was not enough evidence to support a relationship between infant distress and maternal RSA in the reunion episode.

Level-1 Model (7)

$$Maternal\ RSA\ in\ Reunion_{ti} = \pi_{0i} + \pi_{1i}*(Linear\ Time_{ti}) + \pi_{2i}*(Infant\ Distress_{ti}) + \pi_{3i}*(Linear\ Time*Infant\ Distress_{ti}) + e_{ti}$$

Level-2 Model

$$\pi_{0i} = \beta_{00} + \beta_{01}*(Average\ Baseline\ RSA_{i}) + r_{0}$$
$$\pi_{1i} = \beta_{10} + r_{1i}$$
$$\pi_{2i} = \beta_{20} + r_{2i}$$
$$\pi_{3i} = \beta_{30} + r_{3i}$$

Another alternative for the relationship between infant distress and maternal RSA was explored post hoc. It was possible that a mother's physiological response in the reunion was dependent on the level of distress her infant expressed in the still face episode rather than their level of distress in the reunion episode. To test this hypothesis, average levels of infant distress displayed in the still face episode were entered (person mean centered) as a level 2 predictor of maternal RSA trajectories in the reunion (see Equation 8). This model did not significantly improve fit compared to the base model ($\chi^2(2) = 1.18$, p = >.500). Average levels of infant distress in the still face did not have a significant main effect on the intercept (coefficient = 0.04, p = .491) or linear growth (coefficient = -0.01, p = .382). Variance of the random parameters was better explained by the base model than this model. As such, there was no evidence that maternal RSA trajectories in the reunion were statistically related to infant distress as displayed in the previous episode. Infant distress in all forms was removed from subsequent models.

Level-1 Model (8)

$$Maternal\ RSA\ in\ Reunion_{ti} = \pi_{0i} + \pi_{1i}*(Linear\ Time_{ti}) + e_{ti}$$

Level-2 Model

$$\pi_{0i} = \beta_{00} + \beta_{01}*(Average\ Baseline\ RSA_{i}) + \beta_{02}*(Average\ Infant\ Distress\ in\ SF) + r_{0}$$
$$\pi_{1i} = \beta_{10} + \beta_{11}*(Average\ Infant\ Distress\ in\ SF) + r_{1i}$$

Hypothesis #5: Maternal RSA Trajectories in the Reunion and their Relation to Maternal Depressive Symptoms

The influence of maternal depressive symptoms and maternal anxiety symptoms on maternal RSA trajectories in the reunion were tested separately and in combination. First, maternal depressive symptoms (grand mean centered) were entered as a level-2 predictor of the intercept and slope (as per hypothesis #5). This model did not significantly improve fit compared to the base model ($\chi^2(2) = 0.96$, $p > .500$). Maternal depression did not have a significant main effect on the intercept (coefficient = .007, $p = .660$). There remained significant variance in the intercept among mothers in the sample. Depression did not significantly relate to the rate of change of maternal RSA (coefficient = -.002, $p = .415$) and there continued to be significant variation in this parameter. Adding depressive symptoms accounted for 0.73% of the intercept variance and 0.93% of the slope variance between mothers (pseudo R^2s). In sum, hypothesis #5 (part a and b) was not supported, as maternal depressive symptoms in isolation did not predict maternal RSA trajectories in the reunion episode.

Maternal RSA Trajectories in the Reunion and their Relation to Maternal Anxiety Symptoms

In a separate model, maternal anxiety symptoms (grand mean centered) were entered as a level-2 predictor of maternal RSA intercept and slope. There was no improvement in model fit compared to the base model ($\chi^2(2) = 2.90$, $p = .234$). Maternal anxiety did not have a significant main effect on the intercept (coefficient = -0.001, $p = .839$), though accounted for 3.92% of the variance (pseudo R^2) in the intercept between mothers (with significant variance remaining). Anxiety symptoms did not significantly relate to the average rate of change in maternal RSA (coefficient = -0.001, $p = .410$) and accounted for 2.16% of the variance in this parameter.

Hypothesis #6: Maternal RSA Trajectories in the Reunion and their Relation to Maternal Depressive and Anxiety Symptoms

In a combined model, maternal depressive symptoms, maternal anxiety symptoms and their interaction were assessed as level-2 predictors of maternal RSA intercept and slope. This model did not improve model fit ($\chi^2(2) = 2.90$, $p = .234$). As in the isolated models, maternal depressive symptoms and maternal anxiety symptoms did not have significant main effects on the intercept or linear slope. Further, the interaction between depressive symptoms and anxiety symptoms was not related to the intercept or slope (coefficient = 0.00006, $p = .927$, and coefficient = -0.0004, $p = .816$, respectively). Collectively, these terms accounted for 4.60% and 3.40% of the variance (pseudo R^2s) at the intercept and slope. The random components of the intercept and slope remained significant.

In sum, the data do not support the replication of Oppenheimer et al.'s (2013) maternal depression x infant distress model in the reunion episode because the infant distress parameter lacked significant between-subject variance. Further, there was no evidence to suggest that maternal depressive symptoms, anxiety symptoms or their interaction were related to maternal RSA trajectories in the reunion episode. As such, no support for hypothesis #6 was found. Yet, variance in the intercept and slope parameters remained, justifying further examination of between-subject predictors.

Hypothesis #7: Maternal RSA Trajectories and Maternal Emotional Availability

The next model tested whether maternal emotional availability (EAS composite scores grand mean centered) was related to maternal RSA trajectories in the reunion episode (hypothesis #7). The inclusion of maternal EAS scores did not significantly improve model fit, ($\chi^2(2) = 1.10$, $p < .500$). Maternal emotional availability did not have a significant main effect on the intercept (coefficient = -.0002, p = .964) and accounted for 0.93% of the variance in the intercept. Maternal emotional availability was also not significantly related to the rate of change of maternal RSA (coefficient = -.0003, p = .571). EAS scores accounted for 1.85% of the variance in the slope. There continued to be significant variance between mothers in the intercept and slope. As such, this model did not show evidence that maternal emotional availability relates to maternal RSA trajectories when examined in isolation (hypothesis #7, part a and b).

Hypothesis #8: Maternal Emotional Availability in Interaction with Maternal Depressive Symptoms and Maternal Anxiety Symptoms to Predict Maternal RSA Trajectories

The final set of models in the reunion episode tested the interactive effects of maternal emotional availability, maternal depressive symptoms, and maternal anxiety symptoms (discussed in hypothesis #8). The first model tested the hypothesis that maternal depressive symptoms and maternal emotional availability would interact to predict maternal RSA in the reunion episode. Maternal EAS composite scores (grand mean centered), maternal depressive symptoms (grand mean centered) and their interaction were added as predictors of the intercept and slope. There was not a significant improvement in model fit ($\chi^2(6) = 10.19$, p = .116), although there was a trend towards an improvement considering the number of parameters. There were no significant main effects of maternal emotional availability or maternal depressive symptoms on the intercept (coefficient = 0.002, p = .327, and coefficient = -0.002, p = .821, respectively) or linear slope (coefficient = 0.0005, p = .387, and coefficient = -0.002, p = .506). The interaction between maternal emotional availability and depressive symptoms was not significant at the level of the intercept (coefficient = 0.0006, p = .261). However, there was a significant interaction between caregiving and depression on linear slope (coefficient = 0.0003, p = .015), indicating different trajectories for varying combinations of low and high emotional availability and depressive symptoms. Collectively, these three predictors accounted for 20.06% of the variance (pseudo R^2) in linear growth. Although there was little evidence for the influence of maternal caregiving x depression on the intercept, this model strongly suggested that this interaction is important for understanding the rate of maternal RSA change in the reunion episode. As such, a parsimonious model excluding these predictors at the level of the intercept was tested.

The next model included maternal caregiving behaviours, depressive symptoms, and their interaction as predictors of linear growth (not the intercept; see Equation 9; see Table 10). This model significantly improved fit compared to the base model ($\chi^2(3) = 8.02$, p =.045). Maternal caregiving behaviour did not have a main effect on maternal RSA slope (coefficient = 0.0006, p = .279), nor did maternal depression (coefficient = -0.002, p = .504). However, the interaction between maternal EAS and depression was significant (coefficient = .0003, p = .008) and accounted for 19.75% of the variance in slope between mothers (pseudo R^2)[15]. As seen in Figure 11, all trajectories show a general decline in maternal RSA over time. This is consistent with the idea that the reunion is a stressful task for mothers and that physiological stress activation is useful for re-engaging the infant. However, as hypothesized, these results show that RSA trajectories differ at the start and end of the reunion episode (hypotheses #8a and #8b, respectively), consistent with the two tasks of this segment: relational repair and self-recovery.

[15] An online simple slope computation tool (quantpsy.org; Preacher et al., 2006) was used to further probe the interaction of maternal caregiving behaviour and maternal depression on the linear slope of RSA. This online tool requires predictors to be entered at the intercept and slope level and therefore could only be computed on the non-parsimonious maternal depression*caregiving model (i.e., the model with depressive symptoms, caregiving behaviour and their interaction entered as predictors of the intercept and slope). Linear growth was significantly different from zero in the slopes of mothers with low depression and high sensitivity (β = -0.05, SE = 0.02, z = -2.68, p = .007) and mothers of high depression and low sensitivity (β = -0.08, SE = 0.02, z = -4.20, p < .001). Regions of significance tests indicated that the RSA slope of mothers with low depression was significantly different from zero at levels of EAS composite scores above -5.65 (grand mean scored). RSA slopes of mothers with high depression were significantly different from zero at levels of EAS composite scores below 8.87 (grand mean scored). These findings provide additional detail to the interaction slopes in Figure 10.

The findings from this model confirm both forms of hypothesis #8, such that maternal depressive symptoms and maternal caregiving behaviour interact to predict physiological success within both of these tasks. Figure 11 shows that mothers with low depressive symptoms and greater emotional availability display a moderately decreasing slope, suggesting greater success with re-engagement (hypothesis #8a) and with recovery (hypothesis #8b). In comparison, mothers with higher depressive symptoms and less emotional availability have higher RSA at the beginning of the reunion (less RSA dampening to aid in re-engagement; hypothesis #8a) and a faster decline in RSA as the reunion goes on (less RSA recovery over time; hypothesis #8b). Mothers with greater emotional availability and higher depressive symptoms showed more favourable RSA slopes than mothers with less emotional availability and less depressive symptoms. In sum, this model found evidence for the hypothesis that maternal depressive symptoms and maternal caregiving behaviour interact to predict maternal RSA in the reunion episode. It is the combination of these maternal factors, rather than their independent associations, that are important for understanding maternal parasympathetic regulation in the reunion episode.

Level-1 Model (9)

$$Maternal\ RSA\ in\ Reunion_{ti} = \pi_{0i} + \pi_{1i}*(Linear\ Time_{ti}) + e_{ti}$$

Level-2 Model

$$\pi_{0i} = \beta_{00} + \beta_{01}*(Average\ Baseline\ RSA_i) + r_0$$

$$\pi_{1i} = \beta_{10} + \beta_{11}*(Caregiving_i) + \beta_{12}*(Depression_i) + \beta_{13}*(Caregiving*Depression_i) + r_{1i}$$

Table 10

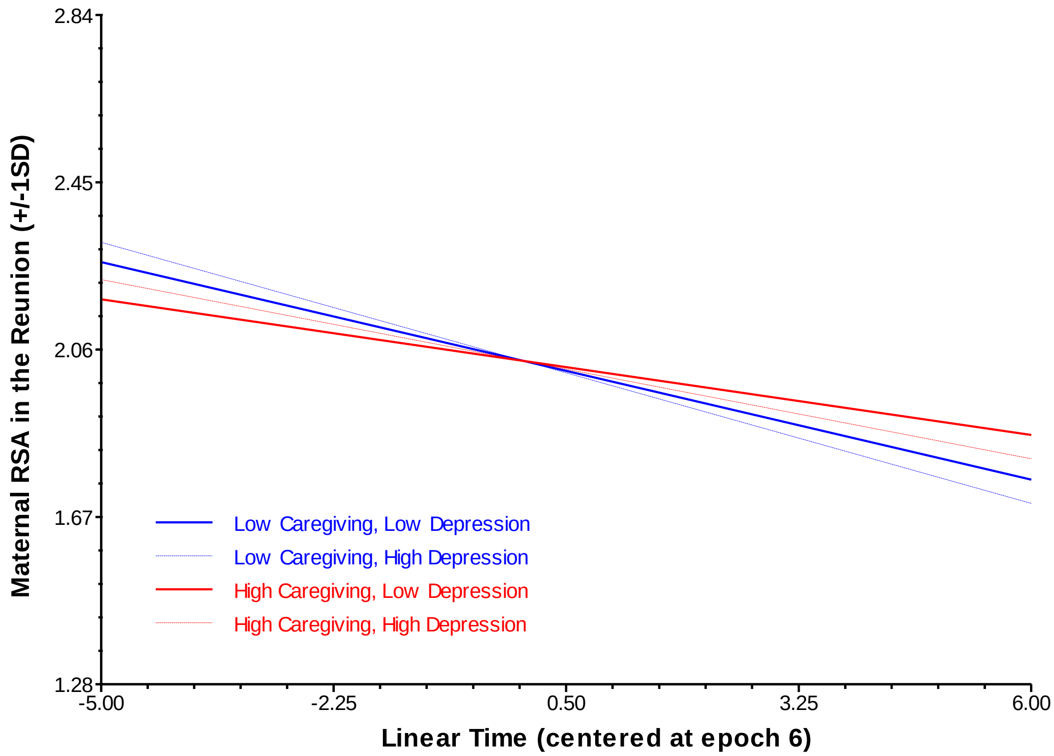
Final Estimation of the Fixed and Random Effects of the Parsimonious Model Examining Maternal Depressive Symptoms, Maternal Caregiving Behaviour, and Their Interaction on the Linear Growth of Maternal RSA in the Reunion Episode

Predictor – Fixed Effect	Coefficient	SE	*t(df)*	*p*-value
Intercept, β_{00}	2.033	0.045	45.40 (81)	<0.001
Maternal Average Baseline RSA, β_{01}	0.912	0.061	14.91 (81)	<0.001
Linear Slope, β_{10}	-0.039	0.011	-3.63 (79)	<0.001
Caregiving Behaviour, β_{11}	0.001	0.001	1.09 (79)	0.279
Depressive Symptoms, β_{12}	-0.002	0.002	-0.67 (79)	0.504
Caregiving*Depression, β_{13}	0.0003	0.0001	2.71 (79)	0.008
Predictor – Random Effect	Standard Deviation	Variance Component	χ^2 (*df*)	*p*-value
Intercept, r_0	0.304	0.092	198.39 (81)	<0.001
Linear Time, r_1	0.051	0.003	118.59 (79)	0.003
level-1, *e*	0.800	0.640		

Note. RSA = respiratory sinus arrhythmia in $\ln(\text{ms})^2$. Maternal caregiving behaviour refers to maternal Emotional Availability Scales composite scores (grand mean centered). Depressive symptoms correspond to maternal scores on the Edinburgh Postnatal Depression Scale (grand mean centered).

Figure 11

Graphical Depiction of the Interaction of Maternal Caregiving Behaviour and Maternal Depressive Symptoms on Maternal RSA Trajectories in the Reunion Episode



Note. The y-axis represents the +/-1SD range of grand mean maternal RSA $\ln(ms)^2$ values in the reunion episode. The x-axis plots the entire range of linear time, centered at epoch 6. Caregiving refers to maternal Emotional Availability Scales composite scores (grand mean centered). Depressive symptoms correspond to total scores on the Edinburgh Postnatal Depressive Scale (grand mean centered). Low and high values correspond to the 25^{th} percentiles and 75^{th} percentiles of those predictors, respectively.

The relationship between maternal emotional availability and maternal anxiety symptoms on maternal RSA trajectories was also tested (maternal depression not included). There was no improvement in model fit compared to the base model ($\chi^2(6) = 6.86$, p =.333). There were no significant main effects of maternal emotional availability or maternal anxiety symptoms on the intercept or linear slope. Further, there was no significant interaction between maternal emotional availability and maternal anxiety symptoms on the intercept or the slope (coefficient = 0.0002, p = .450, and coefficient = 0.00007, p = .136, respectively). The addition of these predictors accounted for 4.70% of the intercept and 12.04% of the slope (pseudo R^2s). This model did not show evidence that maternal RSA trajectories were related to a combination of maternal emotional availability and maternal anxiety.

Finally, a model testing the three-way interaction between maternal emotional availability, maternal depressive symptoms and maternal anxiety symptoms on maternal RSA intercept and slope was tested. This model did not improve fit compared to the base model ($\chi^2(14) = 15.07$, p =.373), which was not surprising considering the number of parameters involved. As in previous models, there were no significant main effects of maternal emotional availability, depressive symptoms, anxiety symptoms or their interactions on the intercept (centered at epoch 6). Collectively, these predictors accounted for 9.67% of the variance in the intercept (pseudo R^2), and significant variance remained. The only significant effect on linear growth was the interaction between maternal emotional availability and depressive symptoms (coefficient = 0.0004, p = .039). Collectively, the predictors accounted for 24.38% of the variance in the slope. There continued to be random variance in the slope component.

In line with the parsimonious model tested for maternal emotional availability and maternal depressive symptoms, this model was reconstructed to exclude these interactions as predictors of the intercept (aside from the inclusion of maternal average baseline RSA as the covariate of the intercept). This model was not a significant improvement compared to the base model ($\chi^2(7) = 9.12$, p =.244). The interaction between maternal emotional availability and depressive symptoms continued to have a significant effect on maternal RSA slope (coefficient = .0003, p = .022), as described previously (see Figure 11). No other main effects emerged. Collectively, these parameters accounted for 20.68% of the variance in growth (little more than the model with only emotional availability and depression).

In sum, these models consistently support the importance of the interaction between maternal emotional availability and maternal depressive symptoms on predicting maternal RSA trajectories in the reunion episode. Although anxiety and depression interacted in the still face episode to predict RSA, anxiety was not supported as a significant predictor in the reunion.

CHAPTER 4: Discussion

This dissertation was developed to better understand how mothers physiologically prepare themselves for and recover from dyadic stress and how this relates to maternal emotional availability, depressive symptoms, anxiety symptoms, and infant distress. Maternal parasympathetic responses to the still face and reunion episodes of the SFP were analysed for this purpose, as the SFP represents the ideal paradigm for measuring physiological reactivity in the context of emotional separation and relational repair. Further, the SFP has been extensively studied and validated, such that the results can be contextualized within the broader literature. By exploiting the nuanced utility of the SFP, this study replicates and extends previous literature: 1) by more fully exploring the main effects and interactions among maternal factors and infant distress on maternal parasympathetic regulation; 2) by examining how the distinct task demands of the still face episode and reunion episode pertain to differences in maternal physiology; and 3) by assessing maternal parasympathetic responses in a dynamic fashion within these episodes. In the still face episode, greater maternal depressive symptoms hindered maternal physiological mobilization in the context of increasing infant distress, and greater anxiety symptoms in the absence of greater depressive symptoms related to PNS hyperarousal in the same context. In the reunion episode, greater depressive symptoms and less emotional availability related to poorer mobilization during initial repair and prolonged stress as the interaction continued. Findings illustrate the importance of context when assessing maternal and dyadic factors in relation to physiology, as the role of predictors differed between episodes. Further, the results emphasize the added value of assessing RSA dynamically rather than statically within an episode, as patterns emerged across trajectories. These summary points are expanded upon below.

Prior to discussing the specific findings from the still face and reunion models, it is useful to review mean RSA patterns across episodes. I examined mean RSA levels in two ways: 1) to ground findings with previous research, I compared average levels of RSA across SFP episodes using a repeated measures ANOVA; and 2) I examined average RSA trajectories within the still face and reunion episodes. First, I will discuss the between-episode mean findings. Consistent with prior research, average maternal RSA increased in the still face episode compared to baseline (Busuito et al., 2019; Ham & Tronick, 2006; Oppenheimer et al., 2013) and returned to baseline levels in the reunion episode (Busuito et al., 2019; see Figure 1). Regarding the still face episode, Busuito and colleagues (2019) reasoned that increases in maternal RSA may be the result of reduced interactive demands on mothers during this episode. Along these lines, it is possible that mothers attempt to calm themselves (e.g., slow their breathing) to comply with the instructions of this episode. With regards to the reunion episode, Busuito and colleagues also found that average levels of maternal RSA returned to baseline levels. Others have found lower maternal RSA in the reunion episode compared to the normal play baseline episode, but only for more sensitive mothers (Moore et al., 2009). In sum, the overall pattern of RSA across episodes in the present study was generally consistent with previous research and suggests that maternal parasympathetic activity shifts according to the interactional demands across the SFP.

Dynamic trajectory analyses provide a more detailed assessment of the temporal shifts in maternal parasympathetic responses within SFP episodes. Within the still face episode, the average maternal RSA trajectory was relatively flat and not significantly different from zero. This average trajectory did not substantiate the average quadratic pattern uncovered by Oppenheimer et al. (2013), characterized by increasing maternal RSA in the first portion of the still face episode and a reduction in the latter half. In any event, the present findings corroborated Oppenheimer et al.'s finding that maternal RSA trajectories differed significantly among mothers. Specifically, there was significant variation in linear RSA slope among mothers in the current sample, such that the flat average trajectory was not representative of all individuals (discussed in detail below). Within the reunion episode, there was a significant decrease in maternal RSA across time, with the rate of decrease differing significantly among mothers (also discussed below). No previous studies have reported on the dynamic trends of maternal RSA within the reunion episode[16]. Collectively, the dynamic assessment of RSA trajectories within SFP episodes provided greater information about average maternal RSA patterns, which were otherwise obscured in between episode comparisons.

[16] Ostlund et al. 2017 only discussed maternal RSA trajectories in relation to infant attunement

Still Face Episode Findings

Specific results from the still face episode will now be discussed. It was determined that maternal RSA trajectories in the still face episode were best estimated by infant distress and its interaction with maternal symptoms of psychopathology. In the parsimonious model (detailed previously, see Table 9), there was a significant main effect of infant distress, such that greater distress was associated with increased maternal RSA. This main effect fits with the previously described pattern of average maternal RSA increase during this episode (Busuito et al., 2019; Moore et al., 2009). At face value, this effect appears to counter assertions that mothers are physiologically activated by infant distress (Mesman et al., 2009; Oppenheimer et al., 2013). However, there was significant variation in the relationship between infant distress and maternal RSA within the sample, indicating that this effect did not hold true for all mothers. Variance in this relationship was best predicted by maternal depressive symptoms and the interaction between depressive and anxiety symptoms. These findings will be discussed in turn.

First it is worth noting that neither depressive symptoms nor anxiety symptoms had direct main effects on maternal RSA trajectories in this episode. In other words, these psychological domains did not impact the level or rate of change of maternal parasympathetic responses themselves, but rather how parasympathetic responses occurred in relation to infant experience, as also shown by Oppenheimer et al. (2013). Although the lack of main effects may differ from research using traditional adult experimental stressors (e.g., those listed as paradigms of negative valance or arousal by the National Advisory Mental Health Council Workgroup on Tasks and Measures for Research Domain Criteria, 2016), the present findings illustrate the importance of context. Unlike other adult stressor paradigms, wherein the presentation of the stimulus is standard and immediate, the stressor in the still face episode is the provocation and emergence of infant distress. This distress, as portrayed in Figure 2A, builds over time for most infants. Thus, it coheres that differences in parasympathetic reactivity among individuals with greater depressive and anxiety symptoms would emerge under the conditions of increasing infant distress in this episode.

As hypothesized, and consistent with Oppenheimer et al.'s (2013) findings, there was a significant interaction between maternal depressive symptoms and infant distress on maternal RSA trajectories in the still face episode. Mothers with lower levels of depressive symptoms showed RSA withdrawal in response to increased infant distress. That is, mothers with fewer depressive symptoms appear to mount a stress response that is contingent with their infants' experience, which may assist them with mobilizing a caregiving response and preparing other physiological stress systems for activation (Mills-Koonce et al., 2007; Moore et al., 2009; Oppenheimer et al., 2013). In comparison, mothers with higher levels of depressive symptoms showed increased RSA in response to increased infant distress, suggesting a lack of physiological activation in the same context. Oppenheimer and colleagues uncovered this finding in a sample that was selected to over-represent maternal depressive symptoms. The present findings are therefore a replication in a lower-risk community sample and emphasize that even low levels of depressive symptoms correspond to differences in maternal parasympathetic regulation in the face of infant distress.

The pattern of RSA displayed for mothers with greater depressive symptoms is consistent with the literature on inflexibility and inertia in depression (Clark & Watson, 1991; Kuppens et al., 2010; Rottenberg, 2005; 2007). Whereas physiological mobilization is theoretically the more efficient strategy for preparing for imminent re-engagement with their infants, mothers with depressive symptoms maintain a regulatory state that may increase the difficulty of this task.

Oppenheimer et al. (2013, p. 264) speculated that depressed "mothers may have learned to "regulate" physiologically by withdrawing from their infants in order to soothe themselves, though at a cost to the development of the mother-infant relationship". The present data further support this speculation and highlight the importance of goals in self regulation (as centered in the definitions by Thompson, 1994 and Gross, 2007). The current findings suggest that regulatory goals may differ between less depressed and more depressed mothers, with the latter group potentially more focused on maintaining their own calm state, rather than mobilizing to calm the infant (also speculated by Oppenheimer et al., 2013). The notion of dissociation or withdrawal among mothers with greater depressive symptoms is also consistent with cognitive and neurological data that suggest that mothers with this psychological profile may be more geared towards self-oriented versus other-oriented processing. For example, in an fMRI study utilizing an infant cry-response paradigm (Ho & Swain, 2017), mothers with depression showed neural patterns associated with greater self-referential threat and undermined reward-motivation systems compared to non-depressed mothers. The authors used different perspective inductions to uncover these patterns (e.g., imagine yourself as the infant, imagine it is your infant and you have to respond), but they collectively interpreted their findings to indicate greater self-oriented processing. Likewise, a review by Dix and Meunier (2009) outlined several self-referential cognitive biases (e.g., increased self-focused attention, self-oriented goals, negative attributions) in a framework for understanding the parenting difficulties associated with parental depressive symptoms. The present interaction between depressive symptoms and infant distress may, therefore, highlight a possible physiological mechanism underlying the difficulties experienced by mothers with greater depressive symptoms in stressful parenting contexts, though causal research is needed to confirm this pathway.

The interaction between maternal depressive symptoms and infant distress on maternal RSA trajectories was moderated by symptoms of anxiety (see Figure 7). Although higher levels of depression consistently predicted a lack of RSA withdrawal in response to increasing infant distress, the rate of RSA increase lessened when mothers also reported higher levels of anxiety symptoms. This moderation is consistent with Rottenberg (2007) and Friedman's (2007) statements that anxiety may account for reductions in vagal tone among individuals with depression. Functionally, however, the slope of RSA trajectories in mothers with greater anxiety and depressive symptoms still increased in the context of infant distress, such that these mothers may still lack the physiological resources necessary to efficiently respond once the episode has ended. Thus, the combined presentation of higher depressive symptoms and anxiety symptoms appears to correspond with a dysfunctional physiological presentation in the still face episode. Notably, a different physiological pattern emerged when mothers reported greater anxiety symptoms and fewer depressive symptoms. Mothers with this psychological profile display the steepest decrease in RSA in relation to increasing infant distress. As hypothesized, these mothers appear to show evidence of hyperarousal in this context. Collectively, these findings provide physiological support for Clark and Watson's (1991) tripartite model of anxiety and depression, which proposes that anxiety distinctly associates with hyperarousal of stress systems, while depression is characterized by anhedonia. The tripartite model originated from research using psychological measures of depression and anxiety (self- and clinician-reports), rather than research on physiological (or neurological) differences. Nonetheless, the present physiological findings appear to coincide with the somatic manifestations of autonomic hyperactivity (e.g., restlessness, muscle tension) that Clark and Watson identified as core to this pathology. Similarly, the present findings also fit with the fear-based hyperarousal outlined by Friedman

(2007) in his autonomic flexibility—neurovisceral integration model of anxiety and cardiac activation. Specifically, the results support this model's prediction that individuals with anxiety show hyperactivity in the cardiac pathways that prepare them for fight-or-flight.

As reviewed in the introduction, findings pertaining to the relationship between anxiety and parasympathetic reactivity during stress are mixed. Some studies (e.g., Levine et al., 2016) find evidence that adults with GAD display greater RSA reduction compared to those without GAD during a worry induction procedure. Other studies have failed to replicate these differences among a community sample of worriers and non-worriers (e.g., Davis et al., 2002). Further, Kirchanski and colleagues found that individuals with GAD, GAD and depression, and depression alone all responded with blunted RSA during a social stressor task compared to non-clinical controls. Oppenheimer and colleagues (2013) also did not find a main effect of anxiety on maternal RSA trajectories during the still face episode, although they uncovered the same directional trend as found with depression (i.e., increasing RSA in relation to increasing infant distress for more anxious mothers). However, Oppenheimer et al. did not report on the interaction between anxiety and depression, which is where the distinct pattern for high anxiety with low depression emerged in the present study.

Taken together, a few key points can be drawn from the present findings. First, differential patterns of anxiety and depression may exist depending on the combined or isolated presence of these psychopathological features (akin to the tripartite model; Clark & Watson, 1991). Second, there may be differences in RSA responsivity depending on whether symptoms of generalized anxiety or diagnostic classifications are being assessed. Third, the task demands of the still face episode may remove some of the protective features that individuals with anxiety use to buffer feelings of physiological hyperarousal. For example, Borelli and colleagues (2018) found that heart rate activity was buffered in mothers with greater anxiety in the puzzle task when these mothers exhibited more parental control over their children. The authors argued that overcontrol may serve a physiological protective function for these individuals. In the still face episode, mothers are unable to use strategies like overcontrol to manage the situation. Thus, the removal of this strategy may be one explanation for why hyperarousal emerges under these conditions. In all, the present findings emphasize the need for continued investigation of the interaction between anxiety and depression in caregiving contexts.

Emotional availability did not emerge as a significant predictor of maternal RSA trajectories in the still face episode, in isolation or in interaction with infant distress or maternal symptoms of psychopathology. To my knowledge, this was the first investigation on the relationship between emotional availability (or, more commonly, sensitivity) and *dynamic* maternal RSA trajectories. I hypothesized that mothers with greater emotional availability would display the same RSA trajectory that emerged for mothers with low depressive and anxiety symptoms in this sample. Specifically, I hypothesized that these mothers would show moderate decreases in RSA in the context of increasing infant distress, consistent with mobilizing a caregiving response in reaction to infant cues (i.e., Oppenheimer et al.'s, 2013, argument regarding depressive symptoms). Although support for my hypothesis was not found, the present findings are consistent with previous research on maternal sensitivity in this episode. Moore and colleagues (2009) predicted and found that average maternal RSA increased in the still face episode. These authors argued that the diminished interactional demands in the still face episode would correspond to increases in RSA (they cited polyvagal theory as their rationale, although it should be noted that positive social engagement can also promote RSA increases according to this theory; Porges, 2007). Similarly, Busuito and colleagues (2019) found increased average maternal RSA in this episode as well, although they did not examine maternal caregiving behaviour as a predictor. Busuito et al. also rationalized their findings in the context of reduced interactional demands in this episode, though they remarked that this finding ran counter to other assertions that mothers would physiologically react to infant distress (citing Mesman et al., 2009 as an example). Partially undermining the interpretations from these authors, however, is the fact that some mothers (i.e., those with less depressive symptoms) did display RSA withdrawal during this low-interaction period. Thus, it is not the lessened demands themselves that can fully account for the null emotional availability finding. Perhaps instead it is the task demands of the still face that make it an inappropriate context to assess differences in emotional availability on maternal physiology. In the still face episode, mothers are explicitly asked to suppress all reciprocal facial, vocal and behavioural responses to infants. In this way, all mothers are acting emotionally unavailable during this segment. As such, even when emotional availability is assessed outside of the SFP (as it was in this study), the demands of the still face episode may be overriding this factor. For example, more sensitive mothers may indeed be cognitively interpreting their infant's distress differently compared to less sensitive mothers, but they are explicitly asked not to act on these internal cues and may even be over-compensating by using self-regulatory strategies (e.g., deep breathing, dissociation) to help them achieve this difficult task. It would have been interesting to test this hypothesis by explicitly asking mothers about their strategy in a post-procedure interview; this remains an opportunity for future research. Regulatory compensation may be particularly relevant in the still face episode of the SFP compared to cry-response paradigms because the mother is facing their infant rather than independently and passively listening to a tape. Joosen and colleagues (2013) found RSA decreases in more sensitive mothers during a cry-response procedure, as did Ablow et al. (2013)

among secure-autonomous pregnant women. Yet, in both these studies, mothers were free to emotionally react to this stimulus in an unconstrained way. It would be useful to administer both these paradigms in the same sample to test this hypothesis. Based on my present speculations, the role of emotional availability seems more appropriate to examine in the reunion episode compared to the still face episode because interaction is permitted and differences in emotional availability can become salient again.

Reunion Episode Findings

Findings pertaining to the reunion episode will now be discussed. It is first worth discussing the role (or more aptly, lack thereof) of infant distress in the reunion episode. On average, infants showed reductions in distress across the reunion episode (as visualized in Figure 8, panel A), such that they started mildly distressed (e.g., frowning, whimpering) and calmed to a neutral (though not positive) state in latter epochs, consistent with patterns of partial affective recovery in the SFP literature (Mesman et al., 2009). Yet, unlike the still face episode, the inclusion of infant distress did not improve model fit when estimating maternal RSA in the reunion episode. Infant distress showed a trend towards a significant relationship with average maternal RSA trajectories, such that higher levels of distress trended towards higher levels of maternal RSA. However, this did not reach the level of significance. Further, the relationship between infant distress and maternal RSA did not vary significantly, meaning that there was not enough between-subjects variance in this parameter to justify further exploration of these differences. Therefore, compared to the still face episode, it appears that maternal RSA in the reunion episode functions independently from the level of distress displayed by infants. Two post hoc analyses were conducted to assess potential explanations for this lack of association. First, I tested whether the relationship between maternal RSA and infant distress differed depending on the epoch in focus, rather than overall trends in the amount of infant distress displayed. Although there was variance in the relationship between maternal RSA and infant distress at specific time points, this modeling did not improve estimation of RSA trajectories. I also examined whether maternal RSA in the reunion episode was determined by average levels of distress in the still face episode, reasoning that maternal RSA may be in response to the intensity (or lack thereof) of infant distress displayed in the non-interactive segment. This examination, however, revealed no significant relationship between average infant distress in the still face episode and maternal RSA trajectories in the reunion.

I posit two explanations for the lack of an association between infant distress and maternal RSA in the reunion episode. First, it is possible that infant distress does not serve as a 'marker' for mothers in the reunion episode. By comparison, results from the still face episode indicated that infant distress serves as the environmental signal for mothers with fewer depressive symptoms (with or without high levels of anxiety) to mount a physiological stress response. Mothers with greater depressive symptoms (with or without high levels of anxiety), however, show the opposite reaction. Thus, in the still face episode, infant distress serves as the marker for maternal RSA responses, depending on levels of depression and anxiety. Yet, in the reunion episode, it appears that infant distress no longer serves an important indicator for mothers. This may be because certain mothers (e.g., those with fewer depressive symptoms and greater emotional availability) mount a physiological response regardless of their infant's level of distress, knowing that an active caregiving reaction is necessary to repair the relationship regardless of the input received from their infant. It is also possible that it is the interactive component of the reunion that is difficult for mothers with greater depressive symptoms (and less emotional availability) rather than the valence or intensity of infant affect in this episode. In both possibilities, maternal RSA would occur independently from infant distress. A second explanation is the lack of variance among infant distress trajectories, such that most infants calmed over time. The speed of recovery appears to differ among infants[17] (as per the significant infant distress x epoch interaction explored post hoc) but these differences do not contribute meaningfully to maternal physiology. In sum, maternal factors show a significant association with maternal parasympathetic function in the reunion episode, whereas maternal factors interact with dyadic information to predict parasympathetic responses in the still face episode.

The lack of a significant relationship (fixed or random) between infant distress and maternal RSA precluded building an analytical reunion model that was equivalent to the still face model. Thus, it was not possible to test the relationship between infant distress and maternal factors in the reunion episode because there was not enough variance between dyads to warrant this. Although the model predictors are not equivalent between the episode models, it is still appropriate to compare their results because the same participants are included in both sets of analyses and maternal variables were equivalent across conditions. The difference between these analyses, therefore, is that maternal factors directly influenced maternal RSA growth in the reunion episode, whereas maternal factors only manifested as predictors of maternal RSA in the still face episode in the context of infant distress.

Maternal RSA trajectories in the reunion episode were best estimated by the interaction between maternal emotional availability and maternal depressive symptoms on linear growth. Prior to outlining the profiles associated with different combinations of emotional availability and depression, it is useful to briefly revisit the task demands embedded in the reunion episode.

[17] Determining the factors that shape the trajectory of infant distress was not the focus of this dissertation, which would have required examining infant distress as the outcome variable (see Coppola et al., 2016; Haltigan et al., 2014; Kogan & Carter, 1996 as examples).

As detailed in the introduction, the reunion episode represents the most challenging episode for parents (Ham & Tronick, 2006). Mothers are required to repair the relationship with their infant (which theoretically involves physiological mobilization for an active caregiving response; Mills-Koonce et al., 2007; Moore et al., 2009) and to begin the process of recovering their parasympathetic system to aid in sustained social engagement with their infant (as per polyvagal theory; Porges, 2007). The first task relates to the second; a repaired relationship is less stressful and permits recovery to a calmer regulatory state, whereas difficulties (perceived or actual) with repair can increase or prolong stress. Thus, factors that facilitate parasympathetic system flexibility and relational repair are likely to impact the success of both tasks. Evidence for this hypothesis emerged. Mothers with fewer depressive symptoms and greater emotional availability displayed RSA trajectories that were consistent with mobilization at the beginning of the reunion episode and recovery towards the end. Specifically, these mothers had the slowest rate of decline in RSA across the reunion episode, such that they started with lower RSA and declined more slowly towards the end. As such, their profile exhibited greater physiological mobilization during initial re-engagement efforts and less RSA withdrawal over time. These dynamic results portray a more nuanced picture of parasympathetic responses during the reunion compared to standard mean episode examinations.

Consistent with previous studies (e.g., Moore et al., 2009), these findings support an overall decrease in RSA in the reunion. Yet, they also demonstrate vagal flexibility within the same segment. For example, Moore and collaborators (2009) found that more sensitive mothers display greater RSA withdrawal in the reunion episode compared to less sensitive mothers. The present findings align with those of Moore et al., such that more emotionally available mothers with fewer depressive symptoms showed greater RSA withdrawal at the beginning of the reunion. The results also show, however, that the same mothers slow their RSA withdrawal as the episode goes on, a finding that is lost when assessing mean episode responses. Although these mothers have not fully recovered their PNS, their slowed activation represents a shift away from active threat processing to a physiological state consistent with positive social engagement and relational maintenance (Porges, 2001, 2007).

The interaction between maternal depressive symptoms and emotional availability also supported the hypothesis that the reunion episode is the most challenging for parents with difficulties in flexibility and relational repair. Mothers who were less emotionally available and more depressed exhibited trajectories with high levels of RSA at the beginning of the reunion and steep withdrawal as the reunion went on. Thus, their profile showed delayed physiological mobilization and prolonged stress activation (i.e., failure to recover). As previously mentioned, infant distress did not relate to maternal RSA trajectories in this episode. Therefore, this profile occurred for more depressed, less emotionally available mothers regardless of their infants' emotional state. These results confirm what was illustrated in the still face episode; namely, that mothers with greater depressive symptoms are less physiologically effective at preparing for re-engagement. Further, this physiological inefficiency is most salient when depression coincides with reduced emotional availability, i.e., the parenting qualities that can aid in relational repair and move challenging situations in a positive direction (Biringen, 2008).

As stated above, mothers with greater depressive symptoms and less emotional availability also show the steepest RSA withdrawal in the latter half of the reunion episode. Whereas their less depressed, more emotionally available counterparts are beginning to show physiological recovery, these mothers are showing greater physiological activation. This pattern suggests two issues: 1) that these mothers find the ongoing interaction more stressful than less depressed, more emotionally available mothers; and ii) their pattern of activation may undermine efforts in positive social engagement (as per polyvagal theory). In support of the first point, Lunkenheimer and colleagues (2017) found that more depressed mothers showed RSA decreases during a mother-child puzzle task compared to less depressed mothers. The authors interpreted this vagal profile as evidence that these mothers were more distressed by the structured, interactive demands of this task compared to other mothers who may have found it enjoyable, if somewhat challenging. Along these lines, Lunkenheimer et al.'s study also supports the second point, such that the higher RSA output of less depressed mothers corresponded with positive social engagement as predicted by polyvagal theory. Similarly, Miller and colleagues (2015) found that mothers with higher RSA during a puzzle task showed less negative parenting in this context. The same pattern was found in mother-adolescent dyads engaged in conflict and pleasant discussion tasks. Amole and colleagues (2017) found that dyads without depression showed increasing, synchronous RSA patterns in these contexts. Taken together, the literature suggests that greater RSA is beneficial in dyadic contexts where positive social communication is indicated. By comparison, and in line with the present findings, depressive symptoms, and less optimal parenting associate with decreased RSA in these contexts, which may cumulatively undermine the mother-infant relationship.

Of note, the present findings did not show evidence of physiological blunting among mothers with greater depressive symptoms (with or without less emotional availability). That is, more depressed mothers did not show a flat trajectory in the reunion episode, nor did they show this pattern in the still face episode. Rather, the profile of inflexibility was one of context; mothers displayed patterns of parasympathetic increases when mobilization was dyadically indicated, and activation when other mothers shifted towards recovery. It is possible that blunted physiology occurs in more severe presentations of depression. For example, in Amole et al.'s (2017) mother-adolescent discussion task study, flat, unresponsive RSA profiles were found in dyads where both the mother and adolescent been diagnosed with major depressive disorder. In comparison, the range of depressive symptoms in the current sample was relatively constricted and most often subclinical, and replication efforts should be explored in clinical samples.

Contrary to the still face episode, maternal anxiety symptoms did not emerge as a significant predictor in the reunion episode. There was no evidence of an interaction between anxiety and depressive symptoms, emotional availability, or their combination. A few explanations for this difference between the still face episode and reunion episode are possible. For one, mothers regain (or at least can attempt to regain) interactive control in the reunion episode. As mentioned previously, researchers have found parental control to function as a physiological buffer for mothers with high anxiety (Borelli et al., 2018). That finding was derived in a sample of mothers and preschool children, but it is possible that similar self-protection strategies are being implemented by more anxious mothers in the reunion episode of the SFP, though this remains to be tested. The EAS does not directly measure overcontrol, although there are some similarities in the non-intrusiveness scale (e.g., mothers taking control of play, limitations of exploration). Even so, the EAS composite that was used is much broader in its measurement than Borelli et al.'s measure of overcontrol, so it would not have uniquely assessed this type of parenting behaviour. Second, the lack of consistent anxiety findings in the reunion episode may mirror the varying extremes of contingent behaviour that have been found in mothers with greater anxiety symptoms (Beebe et al., 2011). For example, in a sample of mothers and 4-month-old infants, Beebe and colleagues (2011) found that anxious mothers engaged in both overly heightened or overly lowered behavioural and affective contingencies with their infants during face-to-face play. This may translate to physiological reactions that also fluctuate non-linearly. Third, the role of anxiety in this episode may emerge only under examinations of mother-infant physiological attunement. This pattern emerged in Ostlund et al.'s (2017) study, wherein mothers with greater anxiety symptoms had greater physiological synchrony with their infants in the first 30 seconds of the reunion and had infants with greater physiological recovery in the next 30 seconds. Notably, their reunion episode was a minute shorter than the present study's, and so their 'latter' segment is not equivalent to the current results. The quick change in the first minute for these mothers, however, provides some suggestion that a non-linear relationship may be occurring for these mothers over a longer period. All-in-all, there are varied reasons why maternal anxiety did not emerge as a significant predictor in the reunion episode, all of which should be explored in further research.

Influence of Covariates

Findings within the still face and reunion episodes emerged despite inclusion of potential covariates, which were selected based on prior RSA literature. Average baseline RSA was the only covariate to emerge as significant; individuals with higher levels of baseline RSA had higher levels of RSA within both the still face and reunion episodes, and individuals with lower RSA in baseline had lower levels throughout. This finding is consistent with the law of initial values: Physiological change is related to initial measurement value (either basal or pre-stimulus; Oken & Heath, 1962; Wilder, 1958). The incorporation of this covariate thus accounts for differences in initial RSA levels during the baseline period of the SFP, thereby better capturing individual and between-subjects reactivity in the still face and reunion episodes.

Of note, baseline levels of RSA in the present study represent a mother's physiology during the normal interaction portion of the SFP (akin to methods by Feldman et al., 2010; Ham

& Tronick, 2006), rather than a non-interactive, resting format outside of the SFP. As such, this baseline measure is not equivalent to basal RSA, which is related to forms of psychopathology (as per the well-established literature on lower levels of RSA within disorders of depression and emotion dysregulation; Beauchaine, 2015; Beauchaine & Thayer, 2015, Rottenberg et al., 2007). Differences in 'baseline' measurement of RSA during the SFP exist across several of the papers referenced herein and have been noted as a concern within the infant SFP research (Jones-Mason et al., 2018). For example, Busuito et al. (2019) measured maternal and infant 'baseline' physiology during a 4-minute period before the SFP, while infants sat on their mother's laps and read picture books. Moore and colleagues (2009) collected 'baseline' physiology during a 2-minute non-interactive period to limit stimulation of both mothers and infants. Oppenheimer and colleagues (2013) collected baseline RSA before the SFP during a 2-minute segment where mothers and infants watched a Baby Einstein clip on an iPad and used this value as a covariate in their dynamic assessment of maternal RSA during the SF episode. Even in these three examples, there are wide discrepancies between procedures that may limit comparably among studies. Separate baseline assessments are supposed to limit the social interaction and anticipatory stress demands associated with the free play episode of the SFP. Yet, social interaction is still occurring (albeit in a different format) in these examples and still occur just before the SFP begins. Further, there are often differences in physical contact (infant on lap vs highchair) that may impact dyadic physiology (Jones-Mason et al., 2018; Waters et al., 2014) and attentional differences may emerge when reading books or watching clips, as compared to just sitting still (Beauchaine et al., 2019). Thus, it is difficult to ascertain whether the separate baselines are achieving their intended purpose. Fortunately, the present results replicated Oppenheimer et al.'s findings despite differences in baseline assessment procedures.

Aside from baseline levels of RSA, no other potential covariates emerged as significant predictors of maternal RSA trajectories within the still face or reunion episodes. Preliminary analyses uncovered a correlational trend between maternal age and maternal RSA in both episodes, with older mothers tending to show lower average RSA levels. However, maternal age did not emerge as a significant predictor in the multilevel models. Age has inconsistently emerged as a significant predictor of adult RSA in other studies. Busuito and collaborators (2019) found that older mothers had lower levels of RSA in their SFP study, and that age accounted for changes in RSA across episodes. Average maternal age in the present sample and Busuito et al.'s sample was similar[18]. In other maternal RSA studies reviewed, maternal age did not emerge as a significant factor in cases where it was reported. Similarly, a meta-analysis of RSA in adults with and without psychiatric disorders did not find evidence for age as a significant moderator of RSA reactivity (Beauchaine et al., 2019). It is likely useful for future studies to examine maternal age as a possible covariate, but the present findings do not show a significant relationship between maternal age and differences in maternal parasympathetic responding during the SFP. No other demographic variables emerged as significant predictors of RSA either, including marital status, racial/ethnic identity, education level, or family income level, which serve as proxy to systematic factors of oppression that can increase allostatic load (Pascoe & Richman, 2009). Antidepressant use was also considered as a possible covariate considering its contention within the literature on RSA and depression (Kemp et al., 2010; Kemp et al., 2012; Licht et al., 2011). However, the low prevalence of antidepressant use in this sample precluded statistical analysis. Specifically, no mothers reported taking tricyclic antidepressants, which have the strongest evidence base for reductions on basal RSA (Kemp et al., 2010; van Zyl

[18] Mean maternal age in the current sample was 32.00 years (*SD* = 1.70). In Busuito et al. (2019) it was 33.67 years (*SD* = 4.21).

et al., 2008), and only three mothers reported taking SSRIs. Visual examination of means among these mothers compared to others indicated similar ranges for the baseline and still face episodes, but more extreme responding (both high and low) in the reunion episode. Taken together, there was not a consistent pattern of RSA differences in mothers taking antidepressants in this sample. Lastly, the vast majority of the sample was able to maintain an unresponsive facial expression during the still face episode. The few mothers who had greater difficulty with this task did not have any significant differences in RSA. Furthermore, difficulties with maternal still face suppression did not mitigate the intensity of this dyadic stressor, as infants of these mothers had significantly greater distress than others.

Study Strengths

This study furthers scientific understanding of maternal parasympathetic functioning during early dyadic stress in several ways. For one, maternal RSA was examined in both the still face and reunion episodes. Assessment of both episodes showcases the unique task demands within them and how their distinct components associate with maternal parasympathetic responses and their relation to maternal and dyadic factors. Second, maternal RSA was assessed dynamically within the still face and reunion episodes. Whereas most research on maternal RSA during the SFP (and other parent-child stressor or challenge paradigms) has focused on average levels of RSA across episodes, the present study examined trajectories. This level of analysis resulted in a nuanced view of how maternal factors and infant distress interact to shape parasympathetic responses over time. Within this temporal framework, for example, differences in rates of RSA change emerged for mothers with varying psychological profiles and parenting behaviours, yet these differences were masked at the average level in this sample. Second, the present study replicates the work of Oppenheimer et al. (2013), who first examined maternal depressive symptoms and infant distress as predictors of maternal RSA trajectories in the still face episode. The results herein provide support for their most central finding, namely that depressive symptoms appear to impair physiological mobilization in the context of increasing infant distress. This replication is notable and reassuring considering the replication crisis that looms over the discipline of psychology (Lilienfield, 2017; Open Science Collaboration, 2015; Tackett et al., 2017), including developmental psychology (Davis-Kean & Ellis, 2019). Third, this dissertation assessed the unique and interactive associations of maternal emotional availability, depressive symptoms, anxiety symptoms, and infant distress. These factors have been assessed individually and occasionally in some combination within the same model, but not in interaction or across both episodes of the SFP. However, the present results underscore the importance of these features in interaction. For example, the unique role of maternal anxiety symptoms on maternal RSA trajectories in the still face episode was only found under conditions of low depressive symptoms. Likewise, it was the combination of depressive symptoms and emotional availability that related to maternal RSA trajectories in the reunion episode.

The sample of the present study is also a strength. Although replication efforts should be explored in clinical samples, there is utility in examining emotional availability, depressive symptoms, and anxiety symptoms as they exist in a community sample. The current findings emphasize, for instance, the physiological differences that can occur in individuals with subclinical levels of depressive symptoms. Further, the range of anxiety symptoms and emotional availability scores illustrated how varied these phenomena are in typical samples. The findings also add to scientific understanding of how small variations in maternal psychopathology and parenting can have substantial implications for other areas of function (Caldji et al., 2000; Feldman, 2012; Hane & Philbrook, 2012). These small but far-reaching differences highlight a need for more accessible supports for caregivers during the first year of parenthood, as discussed in greater detail in the application section below.

Limitations and Future Directions

This study also offers a foundation from which to expand in future investigations. A discussion of the areas that can be added to or improved in future work is presented.

Parasympathetic regulation was the focus of the present study and reflects the first-line physiological response to stressors (Del Giudice et al., 2011; Porges. 1995). Although flexibility of the PNS is an essential component of regulatory processes, single-system examinations of the stress response are incomplete (as argued in models by Andrews et al., 2013; Bauer et al., 2002; Del Giudice et al., 2011). Several others stress systems are missing from the present investigation, including activity of the sympathetic nervous system, the HPA-axis and the neurological regions (e.g., prefrontal cortex) involved in processing threatening stimuli and organizing regulatory responses (Sapolsky et al., 2000; Ulrich-Lai & Herman, 2009). A more comprehensive assessment of these stress systems and their coordination is needed to fully understand how mothers self-regulate in the context of dyadic challenge. There is precedent for this type of research. For example, Mills-Koonce and colleagues (2007) found that mothers with high cortisol levels and low RSA withdrawal in the reunion episode of the SFP showed the greatest amount of intrusive caregiving behaviour (the outcome variable in their study). In comparison, greater RSA withdrawal in the reunion episode appeared to buffer amounts of intrusive behaviour in mothers with high levels of cortisol. The authors did not find a main effect of RSA on caregiving, further emphasizing the importance of examining these systems in combination. Direct comparisons of the PNS and other physiological systems are also required to further test the theory that inflexibility in the PNS results in greater reliance on the sympathetic-adrenal system pathway (Porges, 2001, 2007). For example, Sturge-Apple and colleagues (2011) found that mothers with more depressive symptoms had low change in PNS responses but hyperarousal in the SNS (assessed as a SNS/PNS ratio) during the strange situation procedure, and that this physiological presentation was related to more problematic parenting behaviour. Studies on how these different systems coordinate in dynamic fashion are limited (and somewhat infeasible when online autonomic methods are compared with salivary collection, as per measurement of the HPA-axis), though should be pursued where possible in future research, as supported by the results of this study and others (Oppenheimer et al., 2013; Ostlund et al., 2017).

In addition to other physiological systems, the present study did not assess maternal cognitive appraisal of the SFP. Cognitive appraisal (i.e., subjective interpretations of environmental stimuli) is core to many stress models, beginning with Lazarus who theorized that cognitive perception of threat serves as the impetus for physiological stress activation (Lazarus, 1966; Lazarus & Folkman, 1984). Further, cognitive appraisal (and its various subcomponents, e.g., perceived relevance, valence, coping potential; Yih et al., 2019) occurs in relation to an individual's goal in any specific situation, and thus their multi-regulatory responses for achieving that goal (Thompson, 1994). There may be various ways that maternal cognitive appraisal mediates the relationship between maternal emotional availability, depression, anxiety, and physiology in the SFP. For example, mothers may interpret infant distress during the SFP as threatening or disruptive to themselves (i.e., self-oriented thinking) or through an empathetic, other-oriented lens (Leerkes, 2010), and this may differ according to levels of maternal emotional availability or psychopathology. Along these lines, Leerkes and colleagues (2016) probed maternal cognition during a cry processing interview following the SFP (and two other infant stress tasks) and found that differences in thinking mediated the relationship between maternal physiological regulation and maternal sensitivity. Specifically, they found that better physiological regulation (defined as RSA suppression from baseline) predicted sensitivity when mothers made fewer negative and self-focused attributions of their infant's distress (e.g., thinking they were crying on purpose, being difficult). The authors speculated that greater cognitive focus on the infant's needs over their own helped mothers produce a physiological response that was consistent with mounting sensitive caregiving behaviour. Similarly, McMahon and Newey (2018) transcribed maternal dialogue during the SFP and found that mothers who made less attuned comments (e.g., misjudgements, maternal projections) scored lower on emotional availability and had infants with greater affective dysregulation during the procedure. These authors did not examine maternal physiology, but their methodology may be useful for examining maternal cognition in situ during the SFP. With regards to depression, Dix and Meunier (2009) outline several cognitive pitfalls and processing errors that may undermine parenting behaviour, including reduction of child-focused goals, negative attributions of child behaviour, and reduced self-efficacy. These features may in turn impair appropriate physiological regulation in the context of dyadic stress, consistent with what emerged in the present study. Future studies should continue to examine the role of maternal appraisal on the relationship between maternal caregiving, psychopathology, and physiological regulation.

Appraisal is not only a component of the stress response but also core to self-regulation (e.g., cognitive change statements, re-appraisal; Gross, 2015; Thompson, 1994). Thus, in addition to the assessments of maternal attributions described in the previous paragraph, it may also be enlightening to probe the presence of and content of maternal coping statements during the SFP. For example, it would be interesting to assess whether mothers of varying levels emotional availability, depressive symptoms, and anxiety symptoms engage in different forms of internalized self-talk during the SFP. It would also be beneficial to determine whether this self-talk is malleable. For instance, can statements associated with threat or self-oriented processing (e.g., “I can’t cope with this”, “my infant is purposely causing me trouble”) be consciously shifted to coping statements or other-oriented processing (e.g., “I can get us through this”, “my infant is telling me they need comfort”), and do these shifts correspond to more adaptive physiology during dyadic stress? This type of research will be discussed below as it pertains to intervention efforts.

Maternal self-regulation was centered at the forefront of this dissertation for two main reasons: 1) self-regulation is a core feature of mounting a co-regulatory response; and 2) research examining maternal physiological regulation as an outcome is lacking, as this feature is often assessed in relation to infant or dyadic outcomes. Despite my conscious decision to focus the investigation on mothers, it is imperative to note that the present results are grounded in their relation to a dyadic process. Mother-infant interactions are inherently dyadic (Feldman, 2012; Rutter & Sroufe, 2000), as is the case in the SFP. In the present study, infant experience, specifically level of emotional distress, was incorporated as a predictor of maternal physiology. This served to assess whether maternal RSA responses were occurring in relation to the intensity of infant emotional cues. However, lacking in the present study was a full examination of the interactive affective, behavioural, and physiological attunement of mothers and infants, which some authors have argued is crucial to understanding individual processes in these early relationships (Beebe et al., 2016). This may be particularly important when the individual of interest is the infant, as it is their system that is still under rapid development. Fortunately, there is a host of research exploring the phenomena of attunement (refer to Atkinson et al., 2016; Feldman, 2007; Harrist & Waugh, 2002; Leclère et al., 2014), including physiological attunement during dyadic stress (e.g., Ham & Tronick, 2009; Laurent et al., 2012; Nofech-Mozes et al., 2019). Deficient in the literature, however, are dynamic and multisystem assessments of physiological attunement during stress, which should be explored in future investigations.

In reviewing the literature on maternal physiological regulation in the SFP, it should be noted that studies of physiological attunement often exclude reporting on individual trajectories (exceptions include Busuito et al., 2019). Yet, results from the present study emphasize the utility of reporting maternal self-regulation in the context of co-regulation, as maternal physiology did not consistently relate to infant emotional responses directly and did so differentially depending on SFP episodes and maternal factors. Consistent reporting of maternal self-regulation in the context of co-regulation may assist with resolving inconsistencies in the physiological attunement literature.

This study focused on the self-regulation of mothers interacting with their young infants. It is well-established that mothers are the primary regulators and early scaffolders of infant regulatory systems (Bretherton, 2010: De Wolff & van Ijzendoorn, 1997). Further, it is still the case in Canada that mothers are the primary users of parental leave (Canada Employment Insurance Commission, 2020). Even so, the role of other caregivers (e.g., fathers, grandparents, stepparents, adoptive parents, foster parents) should not be overlooked. Fathers, for example, are an important attachment figure in early development (Lamb & Lewis, 2010). Further, fathers have unique attachment relationships with their infants, as evidenced by moderate correlations with mother-infant classifications in the same family (De Wolff & van Ijzendoorn, 1997). Thus, different caregivers can have discriminant developmental input on the same child (Braungart-Rieker et al., 2001). There are also many families where infants only have a father(s). For these reasons, replication of the current study should be completed in father-infant dyads, as well as with other caregivers. It may also be informative to assess parental self-regulation during relational stress when another parent is present and compare this to parental self-regulation in a dyadic context within the same study. This type of triadic versus dyadic assessment may uncover additional information about how parents physiologically prepare for co-regulation, and the factors that may lead to a deferment of response when another co-parent is present.

The generalizability of the current findings should also be explored in more diverse maternal (and other caregiver) groups. Most mothers in the present sample were married/common-law, well-educated, and reported income consistent with socioeconomic stability. Further, the majority of mothers (60.20%) were of White/European racial and ethnic identity. Replication within samples that reflect greater representation across socioeconomic standing, spousal status, education status and racial/ethnic identity may provide a more comprehensive understanding of maternal parasympathetic responding in the context of mother-infant dyadic stress.

The results of the present study are limited to the context of the SFP. Many investigators in the stress literature have argued for the assessment of physiological regulation in multiple contexts to better probe aspects of flexibility (e.g., Atkinson et al., 2016; Khoury et al., 2020). A benefit of the SFP is that the still face episode and reunion episode pose unique challenges and thereby allow for assessment of regulation during an emotional separation and an attempted reparation. It has also been argued that assessments of maternal sensitivity and co-regulation are most crucial during distress (Bowlby, 1969; Goldberg et al., 1999), which the SFP permits. Nonetheless, additional examinations of maternal parasympathetic regulation and its relation to maternal emotional availability, mood and anxiety should be explored more fully in other paradigms, preferably within the same study to allow within-subjects (and within-dyad) comparisons. For example, in the present study, it would have been interesting to measure maternal RSA during the 30-minute interaction procedure (difficulties with movement artefacts, notwithstanding). This would have permitted testing the hypothesis that mothers with less depressive symptoms and greater emotional availability have higher RSA during tasks of social engagement. Lunkenheimer et al. (2017), for instance, found that mothers with more depressive symptoms had decreasing levels of RSA during a puzzle task, evincing more distress during a less potent challenge. Multi-paradigm dyadic studies would provide greater detail about the contexts in which mothers become dysregulated, and potentially the weighted importance of dysregulation in certain contexts compared to others on later developmental outcomes.

Further, the present results pertain to regulatory responses measured at one time point. In addition to measuring maternal regulation in more than one dyadic context, it would be useful to apply similar paradigms over time and determine longer-term dynamic shifts in RSA as it relates emotional availability and symptoms of psychopathology. For example, Laurent and colleagues (2011) found that changes in maternal depressive symptomology across pregnancy, and 5- and 18-months postpartum were important predictors of infant SNS-HPA coordination and mother-infant attunement, and that depression predicted different patterns of infant physiological responses depending on the timing of symptom emergence. There is also evidence that greater inflexibility (parasympathetic and otherwise) in depression is related to greater severity (Stange et al., 2017) and poorer treatment prognosis (Panaite et al., 2016). This research in the depression literature suggests that mothers with greater parasympathetic dysregulation in early infancy may have greater challenges at later stages of parenthood as well, pointing to a mechanism for ongoing parent-child dysfunction and intergenerational transmission of psychopathology.

A possible limitation of the present study design involves the relationship between facial movement and vagal tone and the implications of this relationship in the context of the still face episode. The vagus nerve is the tenth cranial nerve and is structurally connected to facial motor processes (Beauchaine, 2001). According to polyvagal theory, the social engagement system, of which vagal tone is an integral part, involves integrated processes between facial muscles, vocal structures, cranial nerves, and cortical structures involved in processing social stimuli (Porges, 2001). Thus, vagal tone is structurally and functionally connected to facial expression, although the degree of this association is unquantified. In the still face episode, mothers are instructed to enact a still, unresponsive facial expression. Thus, the task itself places a restriction on the social engagement system. Lessened interactive demands in the still face episode have been cited as a potential reason for increased mean maternal RSA in this episode (e.g., Busuito et al., 2019; Moore et al., 2009), although authors have not outright pointed to limited facial expressiveness in their discussions. Yet, differences are found among maternal RSA reactivity profiles during this episode, particularly when RSA is assessed dynamically and in relation to maternal factors, as in the present study and others (Oppenheimer et al., 2013). Further, the present study found no differences in RSA between mothers who had consistent still face expressions and those with more difficulty maintaining neutrality in this episode. There was also variation in maternal RSA profiles despite the majority of mothers maintaining a still face expression. Thus, the enactment of a still face does not seem to nullify vagal tone reactivity. Nonetheless, the instructional demands of this episode on RSA are worth considering. This may be particularly relevant when considering emotional availability (or sensitivity), as this factor also relies on facial, vocal, and behavioural output consistent with the social engagement system. The lack of facial and larynx output in the still face episode may be one reason why RSA and emotional availability are not associated in this episode, as discussed above.

Measurement issues concerning the constructs of depression and anxiety are also worth noting. As previously detailed, depression and anxiety are highly comorbid conditions (Brown et al., 2001; Fairbrother et al., 2016; Grigoriadis et al., 2019) and have symptom overlap (e.g., negative affect, as described by Clark & Watson, 1991). Given the widespread difficulties with defining these constructs (e.g., as reviewed in Brown & Barlow, 2005), it is unsurprising that measures of depression and anxiety capture shared variance. The psychological questionnaires used in this study are no different, as the EPDS correlates with measures of anxiety (Matthey et al., 2013) and the PSWQ correlates with measures of depression (Swanson et al., 2011). In the present sample, these questionnaires correlated at $r = .68$, indicating shared variance but also substantial unique variance between them. Thus, although some participants may have scored similarly on both questionnaires, there is evidence that these measures are capturing differences between mood disruptions and anxious thinking. Further, the emergence of an expected interaction between symptoms of depression and anxiety on maternal RSA trajectories in the still face episode buttresses confidence that these measures are differentially tapping into unique entities. Nonetheless, future research should continue to distill the aspects of depression and anxiety that are contributing to maternal parasympathetic regulation in the context of infant distress and emotional availability. In particular, the scales utilized herein focused largely on the cognitive aspects of depression and anxiety (e.g., thoughts of guilt, hopelessness, overwhelm, worry). There may be added benefit to assessing the somatic symptoms associated with these psychopathologies, as these may be more directly tied to autonomic functioning.

Applied Implications

The present findings underscore the utility of universally accessible parenting supports, as well as targeted intervention efforts that reach mothers struggling with emotional availability, depressive symptoms, anxiety symptoms and a combination of these factors. Further, the findings suggest that attention to regulation strategies that may improve parasympathetic flexibility may be useful for parents at-risk of physiological limitations in dyadic contexts. Suggestions for these types of supports and interventions are presented.

As discussed in the limitations and future directions section, maternal cognitive appraisal is a likely mechanism between maternal psychopathology, emotional availability, and physiological regulation. As such, intervention efforts that address this cognitive link may be one avenue for increasing adaptive physiological regulation. An example of the potential for this type of intervention is the work of Bugental and collaborators (2002). These authors investigated the efficacy of a cognitive retraining program on reducing child maltreatment in a sample of families engaged in a home visitation program who were considered high-risk (N = 96; recruited in the perinatal period). The cognitive retraining content was designed to increase parents' feelings of competency and problem-solving efficacy and to decrease feelings of self- or child-blame. Families who received the cognitive retraining program through their home visits showed significant reductions in physical abuse and harsh parenting compared to parents receiving the regular home visitation program. This intervention study did not incorporate physiology, though it may be beneficial to explore this in future research (e.g., pre- and post-evaluations of vagal tone in individuals engaged in the cognitive retraining program). Such investigations may illuminate cognitive pathways for increasing adaptive/other-oriented parasympathetic responding during dyadic stress and establish direction of causality.

Similar to the potential for cognitive reappraisal efforts, there is also some promise that increasing certain emotions, specifically compassion and compassionate love, during moments of duress or challenge may improve parasympathetic function. In one of four studies, Stellar and collaborators (2015) found that RSA increased in participants induced to feel compassion by watching a video of someone discussing a personal loss. In follow-up studies, they found that compassion but not inspiration or pride was associated with increases in RSA (Stellar et al., 2015). They also found that the degree of RSA increase during the compassion-inducing video was related to self-rated and behavioural assessment of compassion. In a parenting context, Miller and colleagues (2015) found support for the protective role of compassionate love in the relationship between parasympathetic physiology and negative parenting during challenge tasks. Specifically, they found that mothers who self-reported greater compassionate love displayed greater RSA during a puzzle task and this in turn predicted engagement in less negative parenting behaviour. Thus, increasing maternal compassion towards infants may be a promising avenue for strengthening maternal parasympathetic regulation during co-regulatory contexts.

Increasing compassion is frequently a subcomponent of mindfulness and mediation efforts. Mediation itself has been associated with enhancement of basal RSA in adult populations. For instance, Kok and colleagues (2013) examined the impact of “loving-kindness mediations” on basal RSA in a community sample. They found that participants who engaged in a six-week program designed to foster this mediation practice displayed increased basal RSA compared to those in the waitlist control, and that this process was mediated by an increase in perceived positivity in social interactions. Mindfulness parenting approaches (Duncan et al., 2009) grounded in similar philosophies contain several elements that could theoretically improve maternal parasympathetic functioning during dyadic stress. For example, Duncan and colleagues outline “mindfulness practices that target [parent’s] autonomic cognitive-affective reactions to escalating emotions and their physiological stress reactivity” (p. 265). These components include compassion, child-focused attention, paced breathing, awareness of emotional reactions, and acceptance of children’s experiences. Each of these regulatory strategies may influence parasympathetic responses and should be explored in future research.

Notably, the types of cognitive, mindfulness and mediation components described are already embedded in several early parenting programs. As reviewed by Leerkes and colleagues (2016), strategies of cognitive re-appraisal and emotion regulation are featured in programs like Circle of Security (Powell et al., 2014) and video feedback interventions (e.g., Juffer et al., 2008). Yet, as Leerkes et al. also pointed out, there has not been testing of these interventions on physiological outcomes. One of the only studies (to my knowledge) to examine the physiological underpinnings of mindfulness in parenting contexts is that by Laurent and colleagues (2017), which examined mother-infant cortisol during the SFP and its relation to measures of general mindfulness and parenting-specific mindfulness in a sample of 91 dyads. They found that greater parent-specific mindfulness predicted greater maternal cortisol recovery following dyadic stress, and that this form of mindfulness buffered infant cortisol reactivity in the context of higher life stress. Replication efforts of this study with RSA represent an encouraging future step towards distilling the potential autonomic impact of mindful parenting techniques.

Most consistently, the present findings highlight the vital need to support mothers who are experiencing depressive symptoms, even at low levels, as this factor impacted both parasympathetic mobilization and recovery during dyadic stress. The adverse impact of depression on parenting and child development is well-established (e.g., Field, 2010; Goodman et al., 2011; Goodman & Gotlib, 1999), and the current results add to this body of evidence.

Further, the findings underscore parasympathetic dysregulation as one of several self-regulatory impairments associated with depression, cumulating with other difficulties including increased parental intrusiveness (e.g., Hakanen et al., 2019), insecure mental representations of the infant (e.g., McMahon et al., 2005), attentional and cognitive biases (e.g., Dix & Meunier, 2009) and other physiological dysregulation during stress (e.g., Laurent et al., 2011). It is beyond the scope of this paper to review interventions for perinatal depression (for examples, refer to Letourneau et al., 2017; Sockol, 2015; Yasuma et al., 2020). However, the intervention processes discussed above (i.e., cognitive re-appraisal, compassion, mindfulness) all target areas of dysfunction associated with depression and have potential as universal preventative strategies. Health care professionals are encouraged to screen for perinatal depressive symptoms, a practice already recommended by the American College of Obstetricians and Gynecologists (2015), though not currently by the Canadian Task Force on Preventative Health Care (2013) as others have criticized (e.g., Hamel et al., 2019). Further, health care professionals working with mothers in the perinatal period should provide supports and information to all mothers reporting depressive symptoms beyond the normal range.

Conclusion

This dissertation examined maternal parasympathetic regulation during dyadic stress and its relation to maternal emotional availability, depressive symptoms, anxiety symptoms, and infant distress. Results from this study emphasize the difference in task demands between the still face episode and reunion episode of the SFP and the importance of assessing RSA responses dynamically within these episodes. In the still face episode, mothers with more depressive symptoms showed a lack of physiological mobilization in the context of increasing infant distress, at high and low levels of anxiety symptoms. This profile suggests that these mothers may have the greatest difficulty mounting an effective co-regulatory response once the still face has ended. Mothers with more anxiety symptoms and low depressive symptoms displayed evidence of hyperarousal in the context of increasing infant distress, pointing to the value of assessing the interaction between anxiety and depressive symptoms. In the reunion episode, mothers with more depressive symptoms and less emotional availability displayed RSA trajectories consistent with difficulties with physiological mobilization during initial re-engagement and increasing stress as the interaction continued. In comparison, mothers with less depressive symptoms and greater emotional availability evinced RSA trajectories that showed mobilization during re-engagement and a shift towards recovery as the interaction proceeded. Given that mothers are their infants' primary regulators, these findings underscore the importance of understanding maternal self-regulation in the context of co-regulation and emphasize the need for increased parenting supports and interventions, particularly for those experiencing depressive symptoms and difficulties with emotional availability.

Appendix A. Demographic and Background Information Form

Background Information

1. Please list the initials, biological sex, and birthday of all your children:

____
____
____
____

2. Current relationship status:
   - ☐ Married / living common-law
   - ☐ Separated
   - ☐ Divorced
   - ☐ Relationship with non-live in partner
   - ☐ Widowed
   - ☐ Single
   - ☐ Other: _____________

2B. If you specified in a relationship (married, common-law, non-live in partner), have you been in this relationship for 12 months or longer?
   - ☐ Yes
   - ☐ No

3. Highest level of education completed:
   - ☐ Primary (grades 1 – 8)
   - ☐ Secondary (grades 9 – 13)
   - ☐ College
   - ☐ University
   - ☐ Apprenticeship
   - ☐ Post-Graduate Degree

4. Current employment status:
   ☐ on parental leave ☐ working ☐ unemployed

5. If unemployed, for how long? (months / years) __________________

6. If working or on parental leave:
   a. Do you work ☐ full-time or ☐ part-time?
   b. How many hours a week do you currently work? _______________ hours
   c. Current occupation or the one you will be returning to (please be specific)
      ____
   d. How long have you been at this job (including time spent in parental leave)? (months / years) ________________

7. Please indicate your partner / spouse's employment situation:
   ☐ on parental leave ☐ working ☐ unemployed

8. If unemployed, for how long (for partner)? (months / years) _________________

9. If your partner / spouse is working:
    a. Do they work ☐ full-time or ☐ part-time?
    b. Their current occupation (please be specific)______________________
    c. How long have they been in this job? (months / years) _______________

10. Please check off all current sources of family income:
    ☐ Work
    ☐ Parental Leave
    ☐ Unemployment Insurance
    ☐ Disability Insurance / Worker's Compensation
    ☐ Family Assistance (Welfare)
    ☐ Other Financial Assistance (please specify) ________________________

11. Please check off your family's annual income range before tax:
    ☐ less than $5,000
    ☐ $5,001 - $10,000
    ☐ $10,001 - $15,000
    ☐ $15,001 - $20,000
    ☐ $20,001 - $25,000
    ☐ $25,001 - $35,000
    ☐ $35,001 - $50,000
    ☐ $50,001 - $75,000
    ☐ $75,001 - $100,000
    ☐ $100,001 - $150,000
    ☐ $150,001 - $200,000
    ☐ $200,001 - $250,000
    ☐ more than $250,000

12. Please check off your family's current housing situation:
    ☐ Renting / Leasing
    ☐ Home Owner
    ☐ Other (please specify) ___________

13. Where were you born?
    ☐ Canada
    ☐ Other: _________________________

14. If you listed Other (born outside of Canada):
    a. What year did you come to Canada: _____________
    b. When you arrived in Canada to live, what was your immigration status?
        ☐ Landed immigrant / Permanent resident
        ☐ Seeking refugee or asylum status
        ☐ Temporary resident (e.g., granted a student or work permit)
        ☐ Other: _____________________________
    c. If non-permanent arrival was listed above, has your status been changed to a permanent resident?
        ☐ Yes
        ☐ No

15. Please check off the ethnic / racial status most applicable for your biological parents:

	Your Biological Mother	Your Biological Father
European/White	☐	☐
African-Canadian / Black	☐	☐
East Indian (e.g., Pakistani, Indian)	☐	☐
Asian (e.g., Chinese, Japanese)	☐	☐
Hispanic / Latino	☐	☐
Aboriginal	☐	☐
Pacific Islander	☐	☐
Other: _______________	☐	☐
Unknown	☐	☐

16. Please check off the ethnic / racial status most applicable for the biological father of your infant?

	Infant's father's biological mother	Infant's father's biological father
European/White	☐	☐
African-Canadian / Black	☐	☐
East Indian (e.g., Pakistani, Indian)	☐	☐
Asian (e.g., Chinese, Japanese)	☐	☐
Hispanic / Latino	☐	☐
Aboriginal	☐	☐
Pacific Islander	☐	☐
Other: _______________	☐	☐
Unknown	☐	☐

17. Please check off whether you have been diagnosed with any of the following over i) your lifetime and ii) the last 12 months:

	Lifetime	Last 12 Months
Allergies	☐	☐
Arthritis	☐	☐
Asthma	☐	☐
Cancer	☐	☐
Convulsions with a fever	☐	☐
Diabetes	☐	☐
Ear Infection	☐	☐
Epilepsy	☐	☐
Heart problems	☐	☐
Kidney disease	☐	☐
Muscle disease	☐	☐

Historical Background Information

For the following questions, please think back to your childhood (up until your 19th birthday) and your family's living situation growing up.

18. Please list your birth mother's birthdate (DD/MM/YY): _____________

19. What was your mother's occupation in your childhood (please be specific):
____

20. What was your father's occupation in your childhood (please be specific):
____

21. If possible, please check off all sources of income that your family received during your childhood (up until your 19th birthday):
    - ☐ Work
    - ☐ Unemployment Insurance
    - ☐ Disability Insurance / Worker's Compensation
    - ☐ Family Assistance (Welfare)
    - ☐ Other Financial Assistance (please specify) _________________________

22. Please list the initials and relation of all children (biological, step, fostered, etc.) who lived in your house until you were 18 years old:
____
____
____
____

23. When you were 18 or younger, did one of your parents pass away?
    - ☐ Yes
    - ☐ No

24. What was your mothers marital situation during your childhood:
    - ☐ Married / living common-law
    - ☐ Separated
    - ☐ Divorced
    - ☐ Widowed
    - ☐ Single

25. Did you live with both biological parents growing up?
    - ☐ Yes
    - ☐ No

26. For how long / until what age did you live with both biological parents? _____ years

27. What was your family's housing situation growing up:
    - ☐ Renting / Leasing
    - ☐ Home Owner
    - ☐ Other (please specify) _____________

28. If your parents switched from renting/leasing to owning their home during your childhood, approximately how old were you when this happened? ______ years

29. Please check off the highest education level of both of your parents:

Mother	Father
☐ Primary (grades 1 – 8)	☐ Primary (grades 1 – 8)
☐ Secondary (grades 9 – 13)	☐ Secondary (grades 9 – 13)
☐ College	☐ College
☐ University	☐ University
☐ Apprenticeship	☐ Apprenticeship
☐ Post-Graduate Degree	☐ Post-Graduate Degree

Appendix B. Infant Affect Coding Scheme

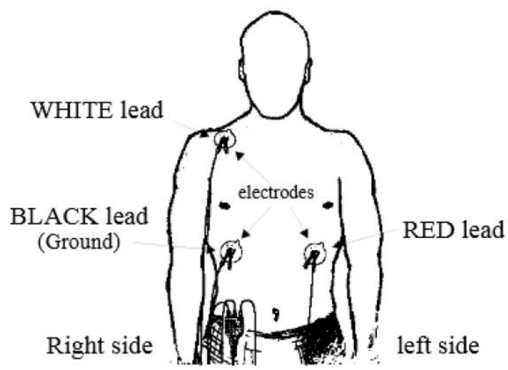
Coding Infant Affect

- Open the BORIS template 'SF Infant Affect Template Boris'.
- Code at the at :000 milliseconds (e.g., 4:12:000).
- Watch the full video before you begin coding to get a sense of what to expect. It will also help orient you to the infant's resting facial expression.
- Code a video in a single session to maintain consistent (reduce number of distractions).
- Re-watch portions of the video until you feel certain about your codes. Write down tricky codes and look back at your decision at the end to see if you still agree. It is best practice to do a random self-reliability check at the end of coding as well, by clicking through several chunks of codes and ensuring that you agree with yourself.
- Go slowly. It is easier to make mistakes when you go fast.
- Be careful to code every second of the task. It is easy to accidentally skip ahead by two seconds. Continuously check your work to ensure you have coded all frames.
- Wear headphones so that audio can inform your codes. Audio is essential for affect coding. An audible yell or whimper trumps a neutral-looking facial expression.
- Non-determinable codes should only be used when there are no contextual clues to place the code. Contextual clues include partial facial expressions, sound, and clips from the adjacent frames. The ND should be used when the coder feels like they would be selecting a code at random, or no better than random.
- For difficult codes, try the following two-pronged strategy: 1) look to the adjacent frames (forward and back) to see differences in changing affect; and 2) watch the video to put the code into context (e.g., does this baby look uncomfortable?).

Infant Affect Code Description	Original 7-Point Rating	Infant Distress 5-Point Rating
Laughing or happy/delighted/interested scream or pronounced vocalization	3	0
Smiling – obvious raised cheek corners, which may be accompanied by cooing	2	0
Cooing / slightly raised cheek corners	1	0
Neutral expression / no obvious expression – no facial discomfort is present	0	1
Frown / distressed face (even slightly) / angry or frustrated expression / whimper – signs of discomfort	-1	2
Yell / protest / negative facial expression higher in intensity than level 2 but not at the highest level of distress	-2	3
Upset crying / upset screaming / highly distressed facial expression	-3	4
Not determinable (e.g., face turned away and no sound) – not determinable via context	ND / System Missing	ND / System Missing

Appendix C. Position of Maternal ECG Electrode Placement

The following diagram depicts the electrode position used to collect maternal ECG data.



Note. This photo was obtained during an internal BIOPAC training at Ryerson University. The original source of this image is unknown and could not be found using Google's reverse image search.

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